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SPECIAL ISSUE

January 2009

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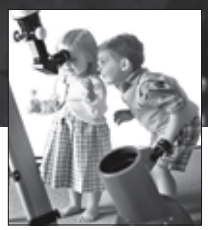

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Astronomy said "everyone should own" the $359 Astro-Tech AT66ED.

Astro-Tech AT66ED

Astronomy magazine said "every once in a while there comes a product everyone should own. This apochromatic doublet is just such a beast . . . a wonderful tool for scanning the Milky Way, and its small aperture and FPL-51 glass let you crank up the magnification on the Moon without false color becoming too intrusive . . . a great grab-and-go scope, a fine little astrograph, a superfinder scope, and a daytime spotting scope."

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VOL. 37, NO. 1

Astronomy January 09

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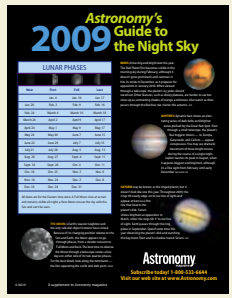

Astronomy's Guide to the Night Sky

This handy four-page insert will keep you looking up all year.

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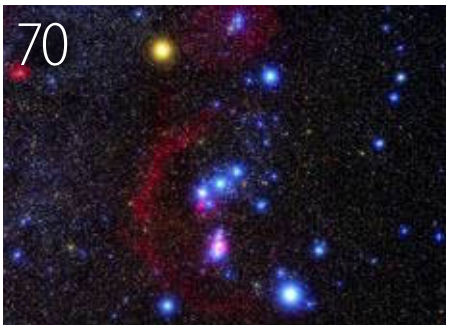

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MEADE

Celebrate the International Year of Astronomy

by David J. Eicher

Some 400 years ago modern science was born. When Galileo Galilei turned his telescope toward the sky and began to make discoveries, human knowledge began a mighty leap forward. The days of ignorance — of guessing or surmising the structure of the Sun, Moon, planets, and the rest of the cosmos surrounding us — were numbered.

Galileo made his first major telescopic observations in 1609. To recognize the 400th anniversary of these legendary observations, the International Astronomical Union (IAU) and United Nations Educational, Scientific, and Cultural Organization (UNESCO) have deemed this year the International Year of Astronomy. The IAU, the governing board of professional astronomy, plans to help world citizens "rediscover their place in the Universe through the day- and night-time sky, and thereby engage a personal sense of wonder and discovery."

Astronomy magazine is proud to be partnering with the IAU and UNESCO to help promote the International Year of Astronomy. The project encompasses a vast number of activities, including "100 Hours of Astronomy," a live webcast; constructing a telescope like Galileo's; bloggers posting diary notes about what it's like to be an astronomer; a "portal to the universe" web site presenting news and other information; spreading awareness of dark skies; and much more. For a complete list of International Year of Astronomy activities, see the web site at www.astronomy2009.org.

We at *Astronomy* will feature a number of our own special events this year to commemorate the 400th anniversary of Galileo's observations. Stay focused on the magazine and our web site, and you'll begin to see them this spring. In this issue, we appropriately kick off the year of discovery with a retrospective article on the past year's top astronomical developments in "Top 10 stories of 2008" by Associate Editor Daniel Pendick (p. 28).

As all recent years have, the past one brought a multitude of amazing science stories, and Dan had a nice dilemma trying to narrow down the choices to just 10. His report covers a spectacular array of topics, including Phoenix landing on Mars; the brightest gamma-ray burst ever seen; the launching of the Fermi satellite; understanding the mechanism that powers aurorae; and the biggest story of the year: observations of Supernova 2008D, the first glimpse of a star in the initial moments of its destruction.

This issue is just one of many special packages we have planned for this year. I have some surprises I'll throw your way in the magazine over the coming months; please let me know what you think. *Astronomy* is the largest circulation magazine on its subject because we give you, the readers, what you want, and I always wish to hear from you with ideas, suggestions, and thoughts about our favorite pastime. Feel free to e-mail me at editor@astronomy.com anytime.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 37, Number 1

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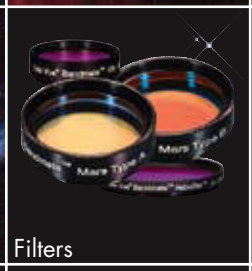
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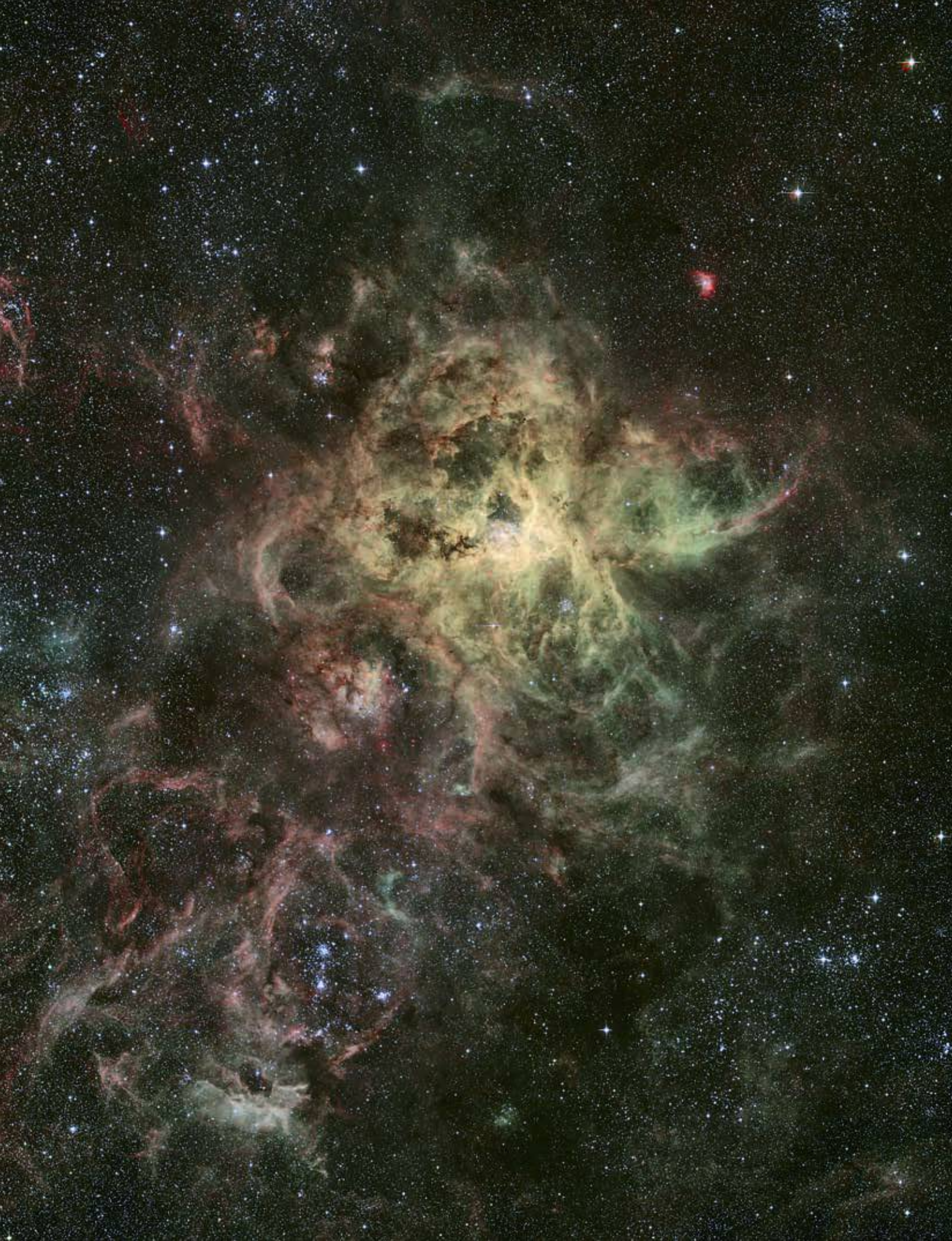
The spider's tangled web

Thick clouds of gas and dust weave the wispy tendrils of the Tarantula Nebula (NGC 2070) — a hotbed of star formation unrivaled in the known universe. The Tarantula lies in the Large Magellanic Cloud, a companion galaxy to the Milky Way located some 170,000 light-years from Earth. To Northern Hemisphere observers, our galaxy's Orion Nebula (M42) reigns supreme. Yet the Tarantula puts M42 to shame. The spidery ribbons span nearly 1,000 light-years and hold at least a half million times the Sun's mass. To put the Tarantula in perspective: If it were as close as M42 (1,500 light-years away), it would cover one-quarter of the sky and shine bright enough to be seen during daylight. European Southern Observatory



Going faster than the speed of light

Just when I've explained to myself for the hundredth time why nothing can exceed the speed of light, I find someone who says it can! In his piece "Is there an end to cosmology?" (August 2008), Abraham Loeb says that with finite time, the accelerated expansion of space moves any distant galaxy away from us at a speed that exceeds even that of light. So tell me, did I miss something, or do I have to start learning this all over again? **— George Charney,** Grosse Ile, Michigan

No material particle can move faster than light relative to its immediate environment. This is a consequence of Einstein's special theory of relativity. But as soon as Einstein added gravity (in the context of his general theory of relativity), he realized that space itself is a dynamic quantity. In other words, space can expand somewhat like the surface of a balloon (except that space is three-dimensional, and the balloon surface is two-dimensional).

Now let's imagine ants walking on the surface of a balloon. If the balloon is blown rapidly enough, the ants will be moved away from each other at a speed that exceeds their walking speed. Similarly, space itself can expand at a speed that exceeds the speed of light.

In our comparison, particles of light are analogous to ants, and the expanding space resembles the inflating balloon. If space is spreading out rapidly enough (as is the case for an accelerating universe), then our galaxy could separate from a distant galaxy at a velocity that exceeds the speed of light.

This is not in violation of special relativity because the two galaxies are far from each other, and there is no fundamental restriction on how fast space can expand across large scales. Relative to their immediate environments, the two galaxies might not be moving at all. Even if the ants stood still, they would be pulled away from each other at some relative speed as the balloon expanded. **— Abraham Loeb,** Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts

Hunting globulars

I enjoyed Stephen James O'Meara's challenge in his September 2008 column, "Naked-eye denizens of the galactic deep." While my 12" RCX400 is in for repair, I am using my binoculars instead. I found all five globular clusters in one night (three with my naked eyes). The most challenging was M15, as the sky is a bit light-polluted in that direction (toward Toronto). M13 and M22 were the easiest to spot, but required binoculars. I tried to see them with my naked eyes, but the objects were beyond the threshold. Thanks for the fun challenge. **— David Jenkins,** Ayr, Ontario

A special view of Saturn

In May 1995, as I was setting up my telescopes for an elementary school star party, I realized the children would not be able to see Saturn's rings. In the presentation before going outside to use the telescopes, I told them I had a special treat: They would be able to see Saturn without its rings.

For years thereafter, students and parents would tell me how they still remembered seeing such a special sight. The conventional view of Saturn, with its beautiful rings displayed, is nearly always available. What better way to mark the "Year of Astronomy" than to be able to see a sight available only once in 15 years! **— Wayne A. Sumner,** Ogden, Utah

Astronomy memories

Your introduction to August's "*Astronomy* magazine's first 35 years" pullout poster inspired me to write a memory and a thank you.

In our accelerating universe, the Milky Way could separate from distant galaxies like M100 at a rate exceeding light-speed. Filippo Ciferri

My introduction to astronomy was as a fifth grader. A family visitor took me outside and showed me the outline of Orion. I was always looking up after that.

Years later, my wife gave me Donald Menzel and Jay Pasachoff's book, *A Field Guide to the Stars and Planets*. That book and 7x35 binoculars gave me access to the stars. Then, shortly after subscribing to *Astronomy*, I won the second-place prize — a library of 23 books — in the 1990 sweepstakes. Those books expanded my horizons and knowledge. I still use them with my current telescopes.

I encourage astronomy enthusiasts to take a kid outside and foster an early interest in the sky. I also want to thank *Astronomy* for the help you have given me through the sweepstakes library and through your continuing efforts in the magazine. **— David P. Rudeen,** Montague, California

Correction

In the September 2008 issue, the picture on page 16 ("Riding fireballs") shows both the Soyuz TMA-9 spacecraft and the Progress 22 resupply vehicle docked with the International Space Station. The caption incorrectly stated that Progress was docked with Soyuz. **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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Strange Universe

by Bob Berman

Your planets in 2009

Coming up: Observers get a phenomenal year.

We're attracted to the unusual. We never watch Congressional speeches, but we'd probably turn on C-SPAN if politicians dressed as hens. Same with the sky. We snap awake when the solar system cooks up a strange year. So happens, 2009 will deliver.

We'll get four lunar eclipses. Most years offer only two. So it's odd. But there's good odd and bad odd. This is the bad kind. The most unsatisfying type of eclipse — penumbral — will repeat over and over, like the dreadful shirts you get every Christmas. On February 9, part of the Moon will venture into Earth's barely there penumbral shadow. It'll be hard to see any change in brightness. The July 7 eclipse is, amazingly, even worse: no expert could tell it's in progress. Still, many news media will proclaim: "Eclipse tonight! Check it out!"

Nature won't be content with this prank. If you miss it, "nothing" will repeat August 5. To their credit, some almanacs have stopped spotlighting such penumbral eclipses, which merely stirred folks to go out, look up, and feel stupid.

If money is no object, you could fly to Pakistan December 31 and watch 8 percent of the Moon turn dark for a few minutes. A real partial eclipse, even if just a tiny bit of lunar real estate gets whacked. On the spectacle scale it'll rate a 0.6, which is the same as watching your grandmother put on makeup.

In contrast to four lame lunar events, the year also offers a total solar eclipse — and this is worthy indeed. It's the longest totality of the 21st century. Very special, but unfortunately it has a weird track. Like many eclipse addicts, I've studied the weather prospects along the thousands of miles the Moon's shadow will cover July 22. Surely it must cross some desert, some generally sunny area. Nope. First it scoots across India, and will even be total over Varanasi, the wonderful city on the Ganges River. Unfortunately it's the monsoon season, and your chances of observing the Sun are similar to the odds of getting a great burger there.

Then the shadow zooms across China, where it's hot, hazy, and mostly cloudy everywhere, and no one speaks English. The climatological odds approach 50–50 over smoggy, mesmerizing Shanghai, and remain the same in the Pacific. Of course, many will still see that 6-minute totality. Maybe almost half. If you have plans, go for it. As an eclipse lecturer, I'm seven for seven and have grown neurotic about getting my heart broken. One Saros ago (the eclipse cycle of 18 years, 11 days, and 8 hours) in 1991, this same eclipse series produced a winner to our group in Baja. One Saros hence, in 2027, this very long eclipse chain will likely deliver again under the clear skies of Egypt. This time alone is iffy. To all who go: May you be among the lucky ones.

The Sun and planets do extraordinary things in 2009. They won't need chicken costumes.

Let's move to the solidly "good odd" category, starting with our sister planet with her ultra-shiny clouds made of droplets of battery acid. Venus gets super-conspicuous if she reaches the eastern edge of her orbit between January and March. This year, 2009, is the bingo. The sky's premier dazzler will be awesome. Nearly halfway up the sky at sunset, easily seen in broad daylight, there's a shadow-casting winner of a Venus apparition. Best evening: her fairytale magnitude –4.8 meeting with the crescent Moon February 27.

The second-brightest planet has a banner year, too. Jupiter enjoys its most brilliant, closest, largest opposition since the century began. On August 14, it shines at a riveting magnitude –2.9. It's also rising out of the slimy depths of the southern zodiacal swamps. This primo close-visit period will last a jovial 4 years, as Jove ascends from its current home in Capricornus the Sea Goat (whatever that is) to the ever-popular Taurus.

Saturn is odd, too, for a different reason. Its opposition at magnitude 0.7 is the dimmest in 13 years because its rings are edgewise. Since those rings are twice as shiny as its body, their absence creates a lackluster "star" that won't turn many casual eyes toward Leo. Saturn without rings, like spaghetti without meatballs, may not sound appealing, but that thin line across its middle looks intriguing telescopically.

Equally strange: Saturn's moons form an uncommon straight line like Jupiter's as its equator aligns our way. (All the major moons in the solar system circle their planets' equators. Just not ours.) This rare equinox is August 10, rings edgewise to the Sun. Then it goes perfectly sideways to us September 4. Such behavior won't repeat until 2025.

At the rear of the parade, Mars comes on during the fall and winter, explosively brightening below zero magnitude. Look for it right smack in the Beehive star cluster (M44) — on Halloween night.

Bottom line: The Sun and planets do extraordinary things in 2009. They won't need chicken costumes.

Only the Moon.

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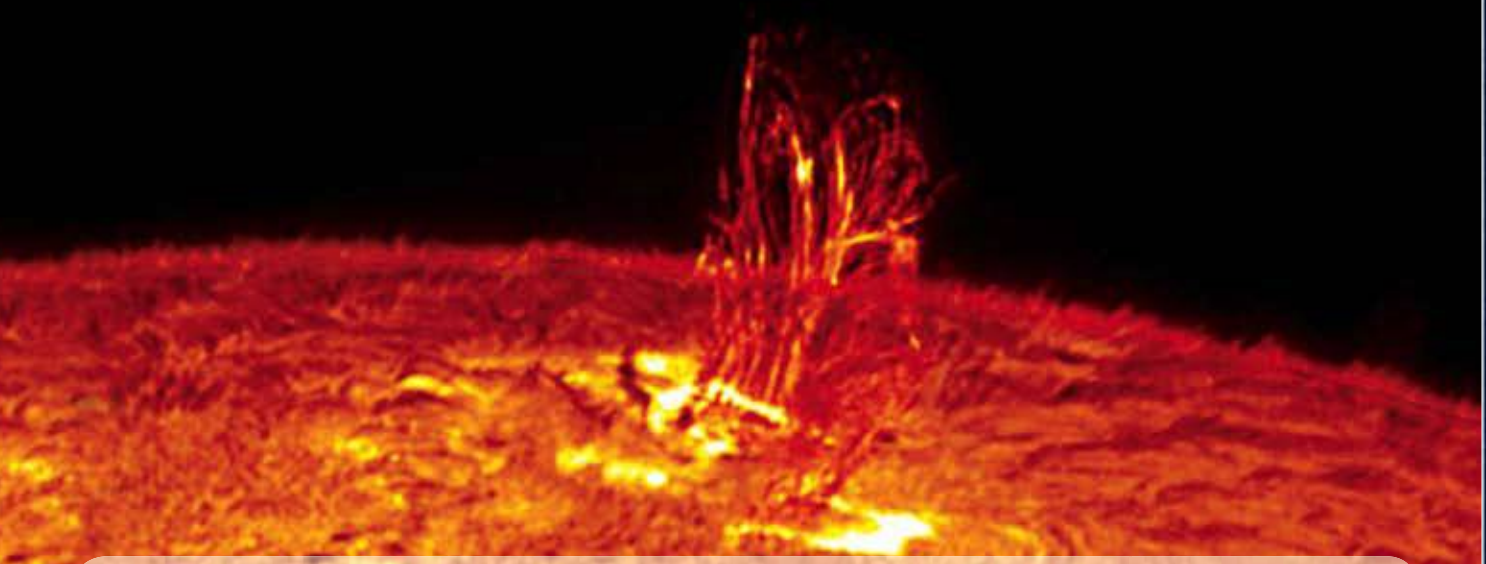

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Secret Sky

by Stephen James O'Meara

A mirror image

Did William Herschel's mind play tricks on him when he observed Uranus?

Last month, I discussed Sir William Herschel's struggle to confirm his suspicion that Uranus has a ring. I also gave reasons to suspect that this "supposed ring" (as Herschel called it) was an aberration caused by the geometry of his "front-view" optical system. This month, we'll investigate some more of Herschel's intriguing ring observations, as well as how the observer's mind may have affected what he saw, or expected to see.

When Herschel first suspected uranian rings, he saw them as "projecting points" of light attending the disk of Uranus, which induced him to visualize a small ring system. After all, when Galileo first observed Saturn in 1610 — only 2 years before Saturn's rings turned edgewise — he did not see a ring, but two attendant points of light framing the planet. Herschel, in fact, did suspect that the points of light around Uranus were rings seen nearly edge-on: "When the surmises arose at first, I thought it proper to suppose, that a ring might be in such a situation as to render it almost invisible; and that, consequently, observations should not be given up, till a sufficient time had elapsed to obtain a better view of such a supposed ring, by a removal of the planet from its node."

Aiding Herschel's growing suspicion that the "projecting points" of Uranus belonged to an edgewise ring system were, arguably, his observations of luminous points on Saturn's nearly edge-on rings in 1789. These "projecting points," he conjectured, may be irregularities in the surface of a solid ring, "like the moon's mountains."

If the uranian rings were also nearly edgewise in 1789, Herschel presumed, they would have tilted more favorably into view in the years that followed — as did Saturn's. But in the decade he had devoted to the search, the suspected rings never got any clearer. So Herschel literally gave up the "ghost," placing "great confidence" in an observation he made March 5, 1792: "I viewed the Georgian planet with a newly polished speculum, of an excellent figure. It [showed] the planet very well defined, and without any suspicion of a ring."

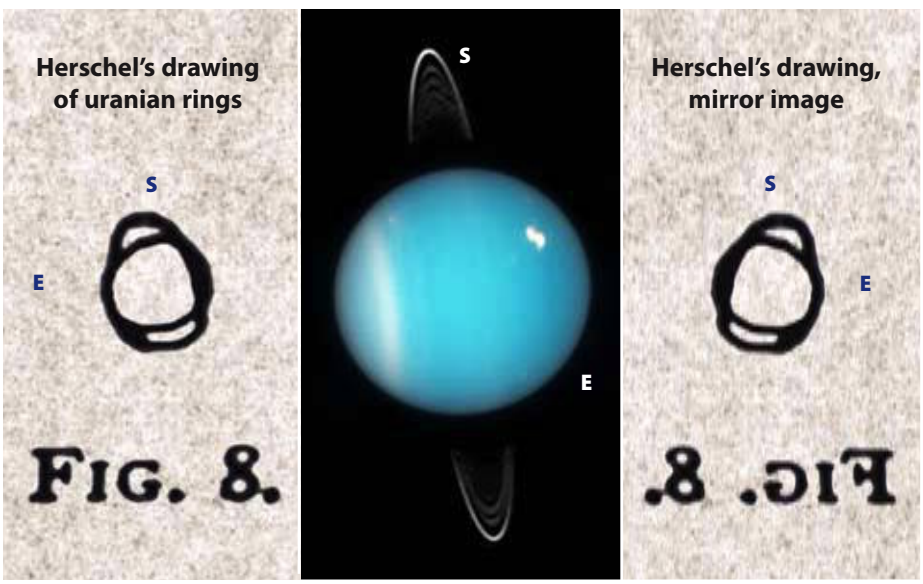
The observer's conclusion was this: "I venture to affirm, that [Uranus] has no ring in the least resembling that, or rather those, of Saturn."

Was Herschel right?

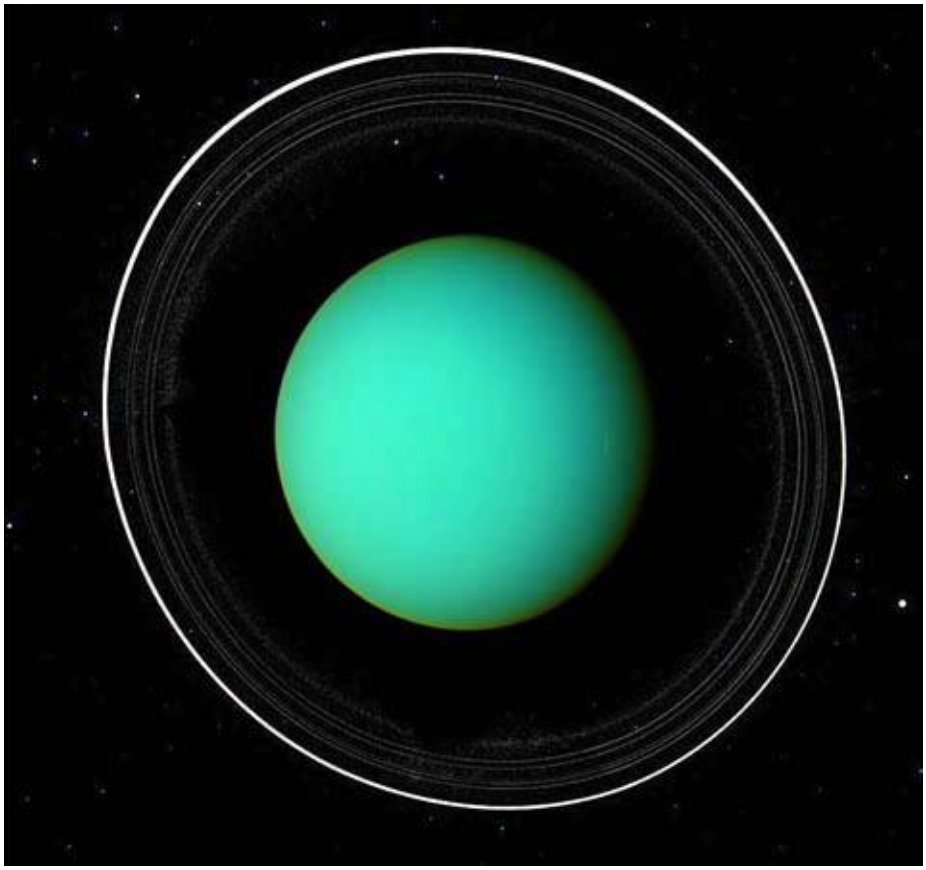
We now know that Uranus has rings and that their orientation to the plane of the ecliptic is peculiar. That's because Uranus orbits the Sun every 84 years with its axis tilted 98° to the plane of the solar system. So the gas giant world rolls around the Sun nearly on its side.

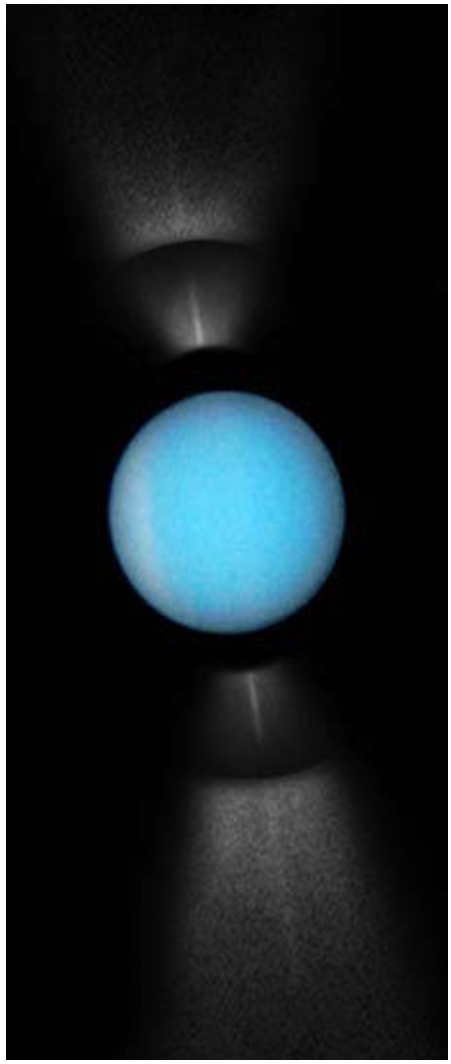
Unlike with any other major planet in the solar system, then, our view of Uranus changes from pole-on to side-on every 21 years. This also means we see Uranus' rings, which lie in the plane of the planet's equator, fully encircling the planet during pole-on apparitions and knife-blade thin above and below the planet during edge-on apparitions.

Unfortunately, Herschel had no knowledge of Uranus' peculiar axial tilt or how it affected our views of the planet. So, while Saturn's rings began to open (and thefore became easier to observe) after its 1789 edge-on apparition, the rings of Uranus were closing — becoming more edge-on. Thus, Herschel's thinking was flawed. The observer was battling not only dual astigmatism in his optical system but also an astigmatic mental image of the changing geometry of Uranus' rings.



Herschel's rough drawing of Uranus (left) may seem to depict its ring system in the correct orientation at first glance. The drawing looks similar to Hubble images of Uranus, which is how it would be seen through a classic Newtonian telescope. But according to Herschel's notes, his drawing shows the planet with south up and east to the left. So, when we flip Herschel's drawing to show it in the same direction as the Hubble image (with south up and east to the right), we discover that Herschel actually drew the mirror image of the planet (right). Uranus image: NASA/ESA/M. Showalter (SETI Institute); drawings: *The Scientific Papers of Sir William Herschel*





Uranus' ring orientation is unusual because the planet's axis tilts 98° to the plane of the ecliptic. In other words, the gas giant rolls around the Sun on its side. So, the view of Uranus from Earth changes from where the rings appear to fully encircle the planet (pole-on, left) to where they appear so thin they are almost invisible (edge-on) every 21 years. Left: Voyager 2/NASA; right: NASA/ESA/M. Showalter (SETI Institute)

Is it possible, then, that Herschel really did see the uranian rings in the late 1780s but lost sight of them as the rings closed?

It gets more curious

Some have argued that Herschel saw uranian rings because he not only had the ring orientation correct but also recorded two other curious characteristics of the ring system — their size and color.

On the evening of March 16, 1787, Herschel noted that "the ring is short, not like that of Saturn … and this may account for the great difficulty in verifying it." We now know that while Saturn's major rings extend to 2.5 planet radii, Uranus' brightest rings extend to only a little less than 2 planet radii.

Herschel also wrote that "the two [rings] … seem of a colour a little inclined to red." Indeed, while Saturn's rings reflect 70 percent of the sunlight hitting them, the uranian rings reflect only a few percent of sunlight. Uranus' dusty rings are, in fact, darker than pieces of charred wood. Is it at least possible that some 220 years ago the uranian ring system was not only denser but brighter? Alas, we may not need to give that matter much thought.

A major flop

In 1787, Uranus' rings were midway between their pole-on (1777) and edge-on (1798) apparitions. They would have appeared obliquely with their major axis running north-northeast to south-southwest. Now look at the only drawing we have of Herschel's suspected ring (his "Fig. 8" from *The Scientific Papers of Sir William Herschel*). It shows how the planet appeared on the nights of February 22 and March 16, 1789. This drawing doesn't have the mirror artifact and was not, in Herschel's estimation, a deception.

At a glance, Fig. 8 may seem to depict the uranian ring system in the correct orientation (see the image labeled "Herschel's drawing of uranian rings" and compare with the Hubble image next to it, page 16). It appears as if Herschel drew the rings obliquely with the major axis running north-northeast to south-southwest, assuming the planet is shown with either north up and east to the left or north down and east to the right, as would be seen in a classical Newtonian. But it doesn't. It shows Uranus with south up and east to the left, as would be seen through his front-view optical system. So Herschel's supposed ring is actually oriented north-northwest to south-southeast — the mirror image of how they should appear (see image labeled "Herschel's drawing, mirror image," page 16).

Perhaps it's best now to let this matter rest in peace. After all, in the end, the great observer was right to be suspicious of the "ring." He was also prophetic: "The observations which tend to ascertain the existence of rings not appearing satisfactorily supported, it will be proper that surmises of them should be given up, as ill founded, or at least reserved till superior instruments provided, to throw more light upon the subject."

Snowy Mars The Phoenix Mars Lander detected snow from clouds about 2.5 miles (4 kilometers) above the spacecraft's landing site. The snow turned to vapor before reaching the surface.

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X ray: NASA/CXC/Columbia/F. Bauer et al; visible: NASA/STScI/UMD/A. Wilson et al

Caught. A supernova's X-ray emission glows blue in this image of the Circinus Galaxy's central region.

20 Galaxy's dark secret exposed

22 Water flowed on Mars for longer

23 Dimmest galaxy has a huge mass

24 First image of planet orbiting a Sun-like star

26 Watching echoes of a supernova

Archival search spots supernova

Astronomers have identified one of the nearest supernovae of the past 25 years — more than a decade after it exploded. The key evidence came from a search of archived observations from 18 different telescopes, a team of researchers reported September 25.

In 2001, astronomer Franz Bauer — now at Columbia University — observed a bright object in the spiral Circinus Galaxy using NASA's Chandra X-ray Observatory. At that time, Bauer and his colleagues did not have enough detailed information to identify the X-ray source as a supernova.

Years later, Bauer's team garnered new clues about the object from the European Southern Observatory's Very Large Telescope (VLT). The researchers then searched through past observations of the Circinus Galaxy.

The combined information identified the star, now known as SN 1996cr, as one of the brightest supernovae ever observed in radio and X rays. SN 1996cr, at a distance of about 12 million light-years, will be a tempting target for future research because it is nearby and significantly brighter than a typical supernova. — **DANIEL PENDICK**

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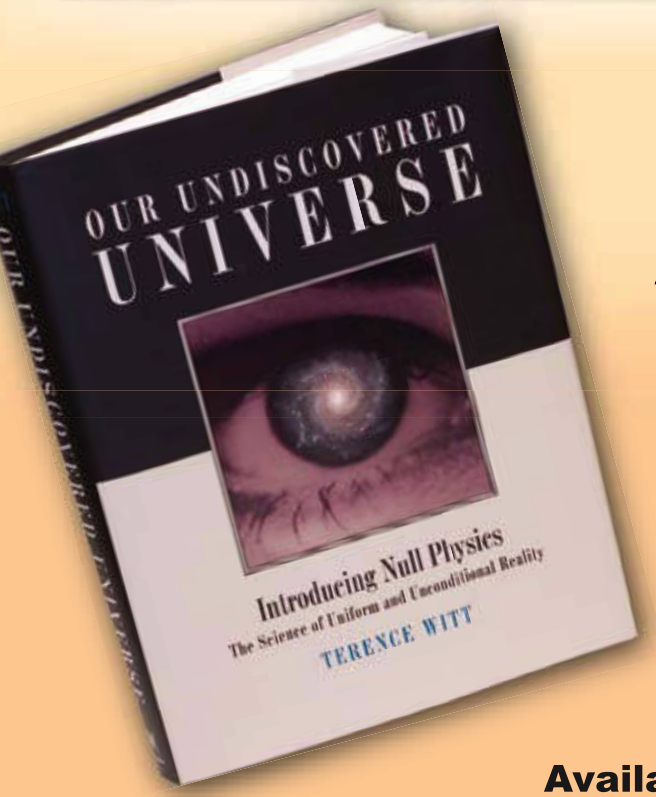

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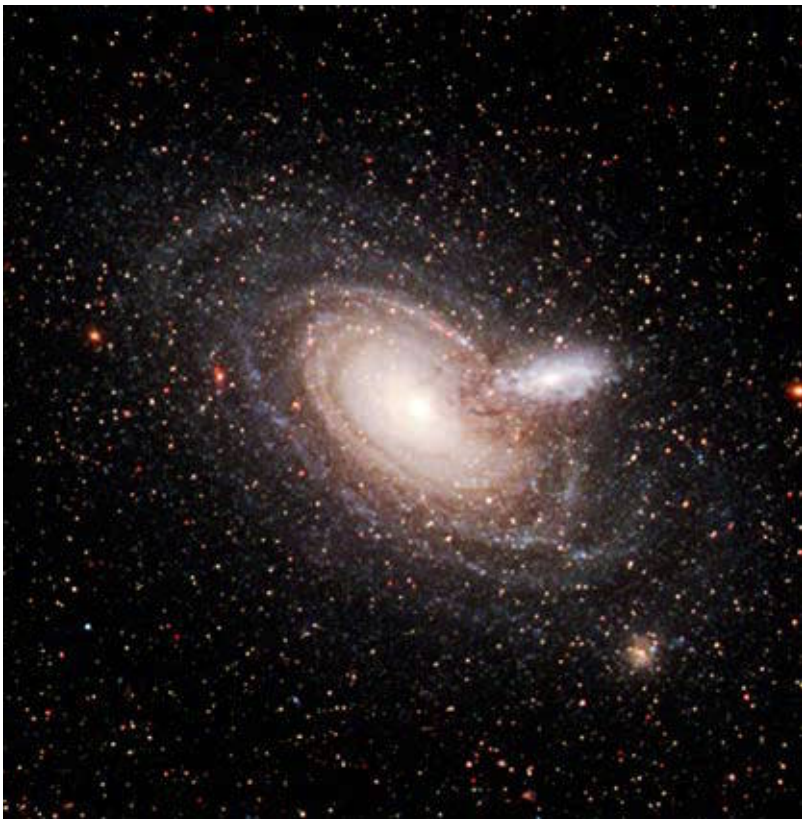
Stardust displayed The Stardust sample return capsule that brought bits of a comet to Earth went on display October 1 at the National Air and Space Museum in Washington.



NASA/ESA/STScI/AURA

Dark zone. **A chance alignment revealed dark, dusty tendrils extending far beyond the illuminated edge of the foreground galaxy in this Hubble Space Telescope image.**

Galaxy's dark secret exposed

NASA's Hubble Space Telescope has captured a rare celestial alignment that betrays a galaxy's dark secret. In the image, a small spiral is silhouetted against the luminous center of a second, larger galaxy — about the size of the Milky Way. The backlighting revealed dark dust tendrils trailing far from the outer edges of the smaller galaxy.

The tendrils are dense enough to filter out most light from any stars that lie within it. Astronomers have never seen dust this far on the outskirts of a galaxy. "We think of the edge of a galaxy as the point where we see the light from stars end," says Benne Holwerda of the Space Telescope Science Institute, who codiscovered the tendrils. "It's surprising to see dusty structures extend so far out from an otherwise unremarkable galaxy."

Holwerda says it's unclear how many spiral galaxies may have such extended dusty tendrils or when these features formed. But the finding has wider implications for the study of spiral galaxies. "There was a general assumption that there was no dust at these radii and that you therefore did not need to worry about it — for instance, when selecting galaxies by diameter," Holwerda says.

Dust has a significant effect on a galaxy's apparent brightness and, therefore, could affect calculations of its distance from Earth. Holwerda and his colleagues calculated the distance to the larger galaxy to be about 780 million light-years from Earth. They believe the smaller galaxy is relatively close to its larger companion, although not so close as to cause the two to interact gravitationally. **— D. P.**

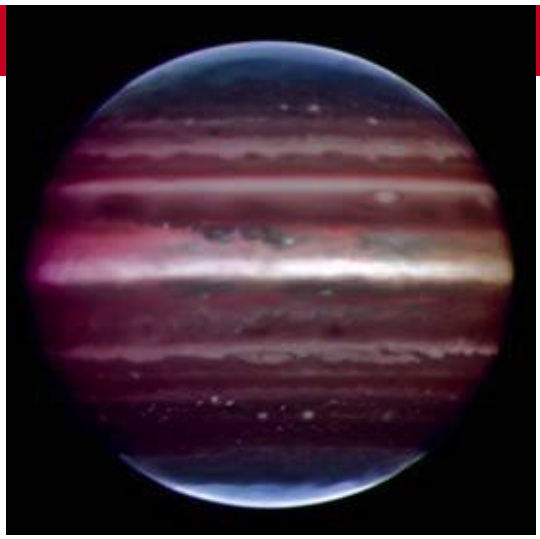
Carina's crib. **Blasts of radiation from young stars sculpt the nebula in NGC 3324, a star-forming region about 7,200 light-years away.** NASA/ESA/STScI/AURA

Hubble shows off spectacular stellar nursery

The Hubble Heritage Project released this stunning portrait of a radiation-sculpted cloud of gas and dust to mark the Project's 10-year anniversary in October. The image highlights NGC 3324, a star-forming region at the northwest corner of the Carina Nebula (NGC 3372).

The sweeping portrait shows the edge of a gas-filled cavity in the nebula. Intense ultraviolet radiation and the "solar wind" of outflowing particles from hot young stars (not visible in this image) have carved the cavity. The cluster ionizes the cavity's gas, setting it aglow.

Dark towers of cool gas and dust rise above the cavity's edge. Dense gas at the tops of the towers resist erosion by ultraviolet light and point toward the stars buffeting the nebula. NGC 3324 is visible only in the Southern Hemisphere. **— LIZ KRUESI**



Looking better! **A prototype blur-reducing system on the Very Large Telescope in Chile created this false-color image of Jupiter, revealing features as small 186 miles (300 kilometers) across.** ESO

Anti-blur technology sharpens Jupiter

Using a new method to correct atmospheric blurring, astronomers with the University of California at Berkeley and the European Southern Observatory (ESO) captured the sharpest image of Jupiter's disk ever made with a ground-based telescope. The researchers unveiled the crisp new portrait of Jupiter October 2.

The technique, called Multi-Conjugate Adaptive Optics (MCAO), is a next-generation version of adaptive optics, a technology that allows an observatory to monitor turbulence in Earth's atmosphere and correct for it over a large field of view. Using adaptive optics, ground-based observatories can meet or even exceed the clear views of the heavens from space-based telescopes.

The Berkeley-ESO team mounted a prototype MCAO system on the 8.2-meter Very Large Telescope (VLT) in Chile. The instrument monitors turbulence at two reference points in the sky and uses this information to correct for the atmospheric blurring of light from the target — in this case, Jupiter.

Conventional adaptive optics systems monitor a single reference point — typically a star, or an artificial one created with a laser beam. In the Jupiter observations, astronomers used the giant gas planet's bright moons Io and Europa.

MCAO sharpens the entire area between the two reference points chosen. With conventional systems, sharpness degrades with increasing distance between the target and the reference star.

"While regular adaptive optics systems provide excellent correction in a small field of view, MCAO provides good correction over a larger area of sky," says team leader and Berkeley astronomer Franck Marchis. "This has a big advantage for looking at large objects, such as planets, star clusters, or nebulae." **— D. P.**

QUICK TAKES

CLOSE LOOK
On October 9, the Cassini orbiter came within 16 miles (25 kilometers) of Enceladus, the craft's closest approach yet to any moon of Saturn.

ASTEROID THREAT
The Association of Space Explorers released *Asteroid Threats: A Call for Global Response* in September. The book outlines a plan to protect Earth from asteroids.

NASA ART CELEBRATED
NASA published a collection of space-inspired art in October to commemorate the agency's 50th birthday.

THE VERNE-BURN
The European Space Agency allowed its Jules Verne spacecraft to burn up over the Pacific Ocean September 29. The automated cargo vehicle had been docked with the International Space Station for 6 months.

TRAVEL OPPORTUNITY
On September 24, the Mars rover Opportunity began an estimated 2-year journey toward a crater called Endeavour, located 7.5 miles (12 kilometers) away.

DUCK!
The International Space Station fired thrusters August 29 to lower its orbit 1.1 miles (1.7 kilometers) to avoid a possible collision with space junk.

BRIGHT FUTURE
On September 2, the PRIMA instrument on the Very Large Telescope Interferometer (VLTI) in Chile saw its first light. PRIMA is a hyper-sensitive instrument for detecting exoplanets.

NEW RING ARCS
NASA's Cassini spacecraft discovered faint arcs of icy particles accompanying Saturn's moons Anthe and Methone, NASA announced September 5.

LAST PLUTOID NAMED
The last of four known dwarf planets received its official name: Haumea. Named for a Hawaiian goddess, Haumea joins fellow plutoids Pluto, Eris, and Makemake.

MARS LIFE TARGETS
An advisory group of 150 scientists chose three martian craters as the best sites for the upcoming Mars Science Laboratory to search for evidence of past life.

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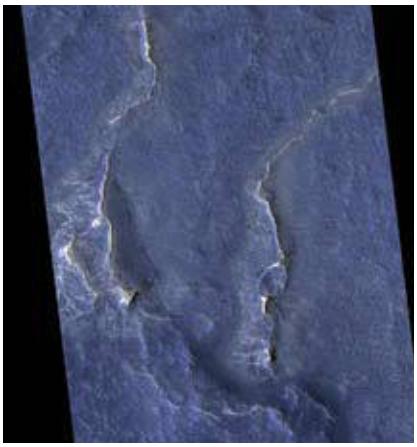


NASA/JPL-Caltech/U. Arizona

Watermarks. The Mars Reconnaissance Orbiter imaged features resembling ancient streambeds on the martian equatorial plains.

Water flowed on Mars for longer

Observations by the Mars Reconnaissance Orbiter (MRO) suggest that water may have flowed on the surface of the martian equatorial belt up to 700 million years longer than previously thought. Catherine Weitz of the Planetary Science Institute in Tucson, Arizona, and colleagues focused their investigation on layered deposits on the plains around Valles Marineris, a huge canyon system near the martian equator. Their findings appeared October 8 in *Geophysical Research Letters*.

MRO's HiRISE camera spotted features commonly associated with flowing water in the layered deposits. This includes inverted stream channels, which form when land on either side of a former streambed erodes away, leaving the more resistant material laid down in the stream at a higher elevation. MRO also imaged valley networks in the layered deposits.

The channels and valley networks are so-called fluvial features, associated with water flowing over a surface. "What we're seeing tells us fluvial activity wasn't occurring just in little pockets over very brief episodes, but rather on a much larger scale for sustained time periods," Weitz says.

Previous research showed that the martian climate had already dried up by the time the layered deposits formed. The new MRO images suggest that wet conditions may have persisted longer on the plains adjoining Valles Marineris. "For some reason, there was precipitation around Valles Marineris that allowed these systems to form out on the plains," Weitz says. **— D. P.**

China's next star in orbit

On September 27, 2008, taikonaut (astronaut) Zhai Zhigang achieved China's first spacewalk during the Shenzhou 7 mission. And although Zhigang had an excellent view of Earth, his spacecraft remained largely out of sight to observers below.

Up until now, Chinese manned spaceships of the Shenzhou series have not been easy observing targets for amateur sky watchers. They are small and relatively dim, orbit low and fast, and circle Earth for only a few days. A sharp-eyed observer might be able to catch a glimpse of Shenzhou for only a minute or two. But now there is a real prospect of a higher, brighter, and longer-lived Chinese space vehicle — the Tiangong orbital laboratory module.

Deciphering announcements of future Chinese space missions is challenging. One issue is simply translating terms that don't correspond one-to-one with English space jargon. There is the additional problem of determining whether the speaker has authority to speak for the shadowy Chinese space administration or is merely an overenthusiastic speculator.

However, after seven Shenzhou missions in the past 10 years — the last three with astronauts — it has become easier to identify reliable sources of information about China's intentions in space. In addition, Shenzhou's success has prompted Chinese government space officials to be much more open about their activities, their plans, and even their problems.

Enough information is now available about Tiangong to understand the basic outlines of China's space lab program. It appears to be a cylinder with a docking port, similar in size and mass to the Shenzhou manned spacecraft. Its design may be derived from Shenzhou's orbital module.

On some past Shenzhou missions, the orbital module — equipped with its own power, communications, and control systems — flew on in orbit for months after the crew cabin had detached from it and returned to Earth. The opposite sequence will occur in the Tiangong mission: A Chinese rocket will launch the space lab into orbit, and subsequent Shenzhou crews will visit it. According to China space program expert Chen Lan, the first Tiangong mission will consist of a simple rendezvous and docking test. It could happen in the next year or two.

By 2011 or 2012, Tiangong could be a fully equipped orbital outpost, able to host visiting crews of Chinese astronauts for a year-long orbit. That vehicle would be the first reliably observable Chinese vehicle in space. Its higher orbit will make it visible from a larger area on the ground.

Bigger space steps require a bigger rocket. In this aspect of its space program, China is taking its greatest leap in capabilities since the 1970s. The Long March 5 rocket, to be launched from a new base on Hainan Island off China's south coast, is not the usual enhanced version of a military missile. It's an entirely new design, from airframe to engines to control systems. The first test flights are expected in 2011 or 2012.

The new booster will be able to carry heavy commercial communications satellites as well as large science probes. A robotic Moon sample return mission is also a possibility. Having the lifting power of an Ariane 5 or the space shuttle, it could launch a Mir-class space station — or even send a modified manned Shenzhou out around the Moon as a nationalistic demonstration.

Actually landing taikonauts on the Moon would require an even bigger rocket, one not yet in the design stage. Despite the Shenzhou program's recent successes, Chinese space officials admit that leaving a footprint on the Moon won't be possible until after 2020. **— JAMES OBERG**

MESSENGER swings by Mercury for another look

NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft visited Mercury October 6 — its second flyby in 2008. The probe passed within just 124 miles (200 kilometers) of Mercury's cratered surface.

MESSENGER needed the swingby to maintain the proper trajectory to achieve orbit around the innermost planet in 2011. At that point, MESSENGER will be the first spacecraft to ever orbit Mercury.

During the October 6 flyby, MESSENGER captured 1,278 new images and gathered other types of data. As in its previous visit January 14, the probe imaged portions of Mercury never seen before by spacecraft. A parting shot shows extensive rays emanating from several impact craters. **— D. P.**

Impact zone. Two planets collide in this artist's rendering of a world-class catastrophe that may explain large amounts of dust in a binary star system 300 light-years from Earth. Lynette R. Cook

What happens when worlds collide?

Dense dust swirling around the binary star system BD +20 307 may be the remains of two rocky planets destroyed in a collision. "It's as if Earth and Venus collided with each other," says UCLA astronomer Benjamin Zuckerman. "Astronomers have never seen anything like this before."

BD +20 307, located about 300 light-years from Earth, consists of two stars orbiting a common center of mass. Past research by Zuckerman and others established that the binary system contains a lot of dust — a million times more than our solar system. Stars surrounded by dense dust are typically a few hundred million years old and just completing the process of planet formation. Dust left over from planet construction gradually dissipates.

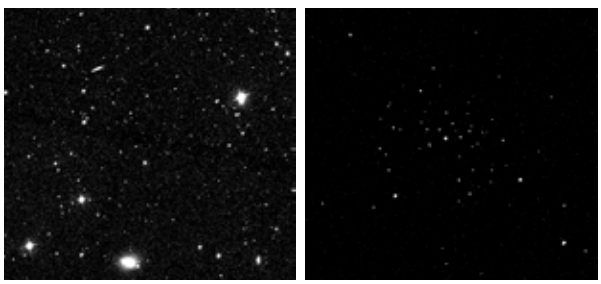
In their latest work, reported in December in *The Astrophysical Journal*, Zuckerman and his colleagues estimated the ages of the stars in BD +20 307. They concluded the pair are adolescents, similar to our Sun. The solar system is likely several billions of years old and past the stage where it should be so dusty.

Because the dust is about the same distance from the binary stars as Earth is from the Sun, the astronomers believe it is debris from a catastrophic collision sometime in the past few hundred thousand years. — **D. P.**

Dimmest galaxy has a huge mass

Astronomers can add another "most" to their list: the dimmest and most dark matter-rich galaxy known. Dark matter neither absorbs nor emits light but is a major ingredient of galaxies.

Called Segue 1, the galaxy is one of about two dozen dwarf satellites of the Milky Way. Marla Geha of Yale University and colleagues used the Keck telescope at Mauna Kea, Hawaii, to measure the motions of 24 stars known to reside in Segue 1. It may have several hundred stars.



SDSS/Marla Geha

Dim suns. In the image at left from the Sloan Digital Sky Survey (SDSS), the dwarf galaxy Segue 1 is virtually indistinguishable from background stars. The image at right isolates the galaxy's 24 known stars from the SDSS star field.

It turned out the stars are moving 10 times too fast for mutual gravitational attraction alone to confine them within Segue 1. To explain that, the galaxy must contain additional mass, about 1,000 times more than exists in its luminous stars alone. The missing mass is dark matter, more than 99 percent of the galaxy's total mass.

This research was slated to appear in *The Astrophysical Journal*. — **L. K.**

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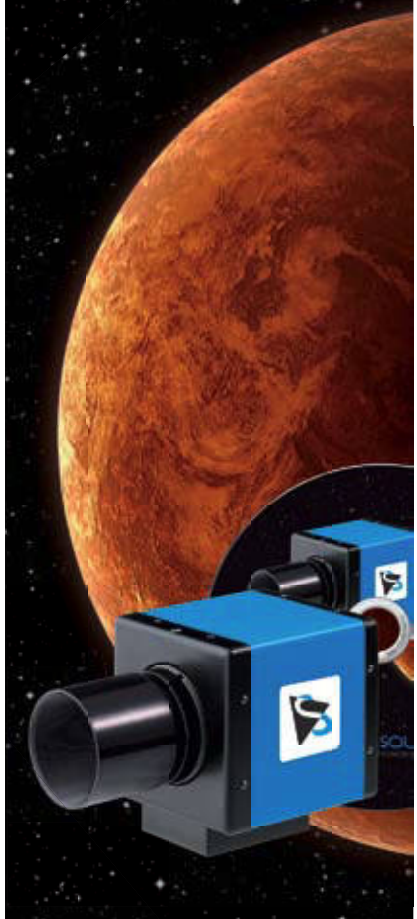

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Most distant burst On September 13, NASA's Swift satellite detected the most distant gamma-ray burst ever seen — 12.8 billion light-years from Earth.

Gemini Observatory

Not so shy. **Astronomers captured this infrared image of a Sun-like star and its likely companion planet.**

First image of planet orbiting a Sun-like star

Astronomers from the University of Toronto captured the first image of a likely planet orbiting a Sun-like star. The young star, 1RXS J160929.1-210524, is located roughly 500 light-years from Earth.

By studying the probable planet's spectra, the astronomers could deduce the object's mass (around 8 Jupiter masses) and temperature. From this information, they determined it's too cold to be a brown dwarf star and is, instead, likely to be a companion planet to the young star. The planet would orbit the young star at 330 times the distance from Earth to the Sun.

The star is similar to ours in a couple of ways. It has a mass about 85 percent of the Sun's and a temperature about 70 percent of our star's. However, it's much younger. While our Sun is roughly 4.6 billion years old, this star is only about 5 million.

In the astronomers' paper, submitted to the *Astrophysical Journal Letters,* they acknowledge the slim possibility this sighting could be a chance alignment of a free-floating star and planet. Additional observations over the next few years should determine whether the planet and star are moving through space together, thus proving the planet orbits the star. — **L. K.**

Ancient galaxies show strong magnetic hearts

Astronomers made the first direct measurement of the magnetic field in a galaxy relatively early in cosmic history — about 6.5 billion years ago. Researchers reported October 2 in *Nature* that the protogalaxy, DLA-3C286, has a surprisingly strong magnetic field. This finding doesn't fit with conventional thinking about galaxy evolution.

According to the leading theory, a rotating galaxy develops an internal dynamo that, like the whirling liquid-iron currents at Earth's core, generates a magnetic field. Astronomers assumed the dynamo would strengthen over time, producing the strongest field in the oldest galaxies.

The researchers studied the protogalaxy using the Green Bank Telescope (GBT) in West Virginia, which is sensitive to radio frequencies. As radio energy from an even more distant galaxy passed through the protogalaxy, hydrogen gas absorbed part of the background object's signal. The GBT's sensitive antenna can measure the type and amount of energy absorbed, which reveals the strength of the galaxy's magnetic field.

If strong magnetic fields were present in the early universe, they may have shaped galaxies' fates more than astronomers thought. "This new measurement indicates that magnetic fields may play a more important role in the formation and evolution of galaxies than we have realized," says team scientist Arthur Wolfe of the University of California at San Diego. — **D. P.**

BRIEFCASE

First asteroid tracked into atmosphere

As asteroid 2008 TC3 approached Earth, NASA scientists tracked it and calculated its path into the atmosphere — a first. As predicted, the asteroid broke up over Sudan October 7 at about 02:46 Greenwich Mean Time (5:46 A.M. Sudan time).

Scientists estimate the object's size at about 6.5 feet (2 meters) across. "We estimate that objects this size enter Earth's atmosphere once every few months," says NASA scientist Don Yeomans. "This event . . . is the first time we have observed an impacting object during its final approach." — D. P.

IBEX is on its way

NASA's Interstellar Boundary Explorer (IBEX) mission launched October 19 from the Kwajalein Atoll in the Pacific Ocean. IBEX will image and map dynamic processes taking place where the Sun's outflowing solar wind collides with gas in interstellar space. From its high-altitude Earth orbit, the satellite will monitor particles from the outer solar system called energetic neutral atoms. — D. P.

New mission to Mars

On September 15, NASA announced that a new science mission to Mars will launch in 2013. The Mars Atmosphere and Volatile Evolution mission (MAVEN) will advance understanding of the Red Planet's atmosphere, climate history, and past suitability for life. Scientists hope MAVEN will help them figure out what happened to the denser atmosphere that at one time allowed Mars to maintain liquid water on its surface. — M. M.

25 years ago in *Astronomy*

January 1984

Astronomy rang in the New Year in 1984 with a feature in the January issue about the Milky Way. "A Bigger & Better Milky Way Galaxy," by celebrated astronomer Bart Bok, discussed new research techniques and how astronomers' picture of our galaxy was changing.

In 1973, scientists estimated the mass of the Milky Way to be around 100 to 200 billion solar masses. The most recent calculation puts our galaxy's mass at around 2 trillion solar masses. "We can deduce from all of this that the study of our home galaxy, the Milky Way, is alive and well," wrote Bok. "New discoveries and unexpected new phenomena make it a constant pleasure to be involved in Milky Way research."

January 1999

10 years ago in *Astronomy*

In January 1999, *Astronomy* showcased images captured by NASA's Hubble Space Telescope and discussed the Hubble Heritage Program in "Hubble looks back," written by the magazine's current editor, David J. Eicher.

"Hubble has imaged more than 10,000 objects, but only a few hundred of the images have been released," Eicher wrote. "Part of the point of the Heritage program is to share images that are just purely pretty but without proven scientific value yet."

NASA inaugurated the Hubble Heritage Program in October 1998. The project continues to release spectacular images to the public. — **MEGAN McCHAIN**

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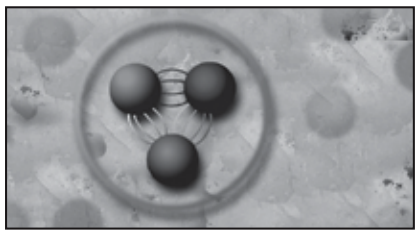

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Model of protons showing quarks

About Your Professor

Dr. Steven Pollock (Ph.D., Stanford University) is Associate Professor of Physics at the University of Colorado at Boulder. He has taught physics courses from introductory physics to advanced nuclear and particle physics. He received the Boulder Faculty Assembly Teaching Excellence Award in 1998. He became a Pew/Carnegie National Teaching Scholar in 2001. He is the author of *Thinkwell's Physics I*, a CD-based textbook.

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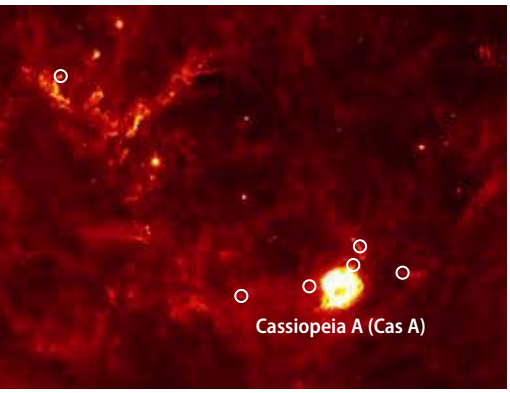
Lucky break After three unsuccessful attempts, commercial launch company SpaceX sent its Falcon 1 launch vehicle into orbit September 28 with a simulated payload.



NASA/JPL-Caltech/E. Dwek and R. Arendt

Second look. **A supernova's initial flash of radiation struck clouds of dust, causing them to glow with infrared light. The Spitzer Space Telescope observed such "light echoes" from these six clumps of dust (circled).**

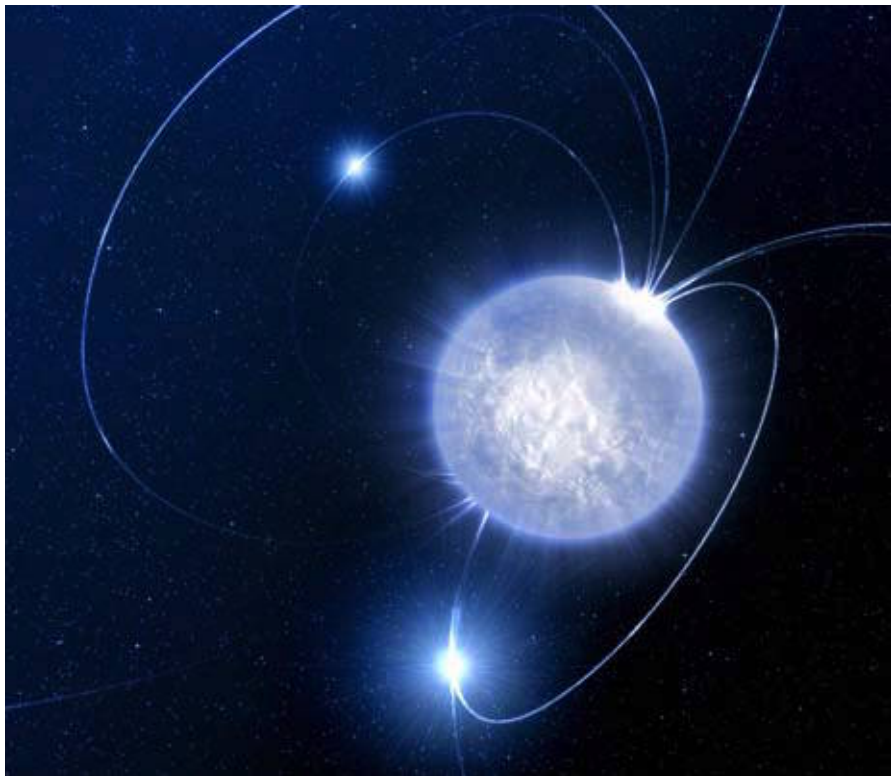
Watching echoes of a supernova

Astronomers have a second chance to study the early flash of an exploding star, thanks to NASA's Spitzer Space Telescope. Today, all that remains of the event is an expanding cloud of stellar debris called the Cassiopeia A (Cas A) supernova remnant. But gas clouds behind the remnant are still glowing after being struck centuries ago by the powerful, short-lived pulse of ultraviolet radiation and X rays that heralded the death of the star, researchers reported October 1 in *The Astrophysical Journal*.

Light from the supernova first reached Earth about 300 years ago, but the event was not officially observed and recorded. In the new research, Eli Dwek for NASA Goddard Space Flight Center and Richard Arendt of the University of Maryland at Baltimore have shown that light emitted by gas clouds near Cas A can provide information about the supernova blast itself.

The astronomers identified six gas clouds — about 160 light-years more distant than Cas A — are emitting infrared "light echoes" from the supernova. The supernova's initial radiation flash expanded in all directions, striking the clouds along the way. Today, the clouds continue to glow weakly in the infrared from that encounter.

Although the supernova's flash has long ago passed by Earth, the light echoes will persist. Astronomers hope that by analyzing the echoes, they can learn more about the spectacular explosion that created Cas A. As radiation reaches additional clouds, they, too, will produce echoes that astronomers should be able to observe. — **D. P.**



Field star. **Magnetars produce intense magnetic fields. As shown in this artist's concept, charged molecules gyrating around a magnetar's magnetic field lines may trigger intense flashes of visible light. Astronomers have observed visible light from a magnetar for the first time.** ESO/L.Calçada

Astronomers report first optical magnetar

Astrophysicists have observed visible and infrared light from a likely magnetar for the first time. A magnetar is a neutron star with an intense magnetic field. Previously, astronomers had observed only X-ray and gamma-ray emissions from magnetars.

NASA's Swift satellite first detected the object by its gamma-ray signal. Astronomers then conducted a multiwavelength telescope campaign to observe the object, Swift J195509+261406.

Following the gamma-ray signal, Swift J195509+261406 emitted an oscillating X-ray afterglow reminiscent of a magnetar. Astronomers also observed 40 optical flares over the first 3 days. The object went silent until it emitted an infrared flare some 11 days after the initial gamma-ray signal.

Swift J195509+261406 is located 15,000 light-years away in the constellation Vulpecula. Two papers concerning this observation appeared September 25 in *Nature*.

Astronomers are unsure whether this infrared and visible emissions are common among magnetars or unique to this one. Simultaneous optical and X-ray observations are needed to learn more about this particular object and magnetars in general. Unfortunately, magnetar outbursts seem to be infrequent events. — **L. K.**

Europeans propose astroparticle plan

The Astroparticle European Research Area (ASPERA) finalized its intended projects for the future of astroparticle physics. The roadmap includes seven new efforts: an array of telescopes to detect cosmic gamma rays; a huge neutrino telescope in the Mediterranean Sea; detectors for dark matter searches; an instrument to study the fundamental nature of the neutrino; a detector for proton decay and neutrino astrophysics; an array to detect charged cosmic rays; and an underground gravitational wave experiment.

ASPERA is made up of 17 national funding agencies in Europe. The European Organization for Nuclear Research in Geneva, Switzerland, is also involved. — **L. K.**

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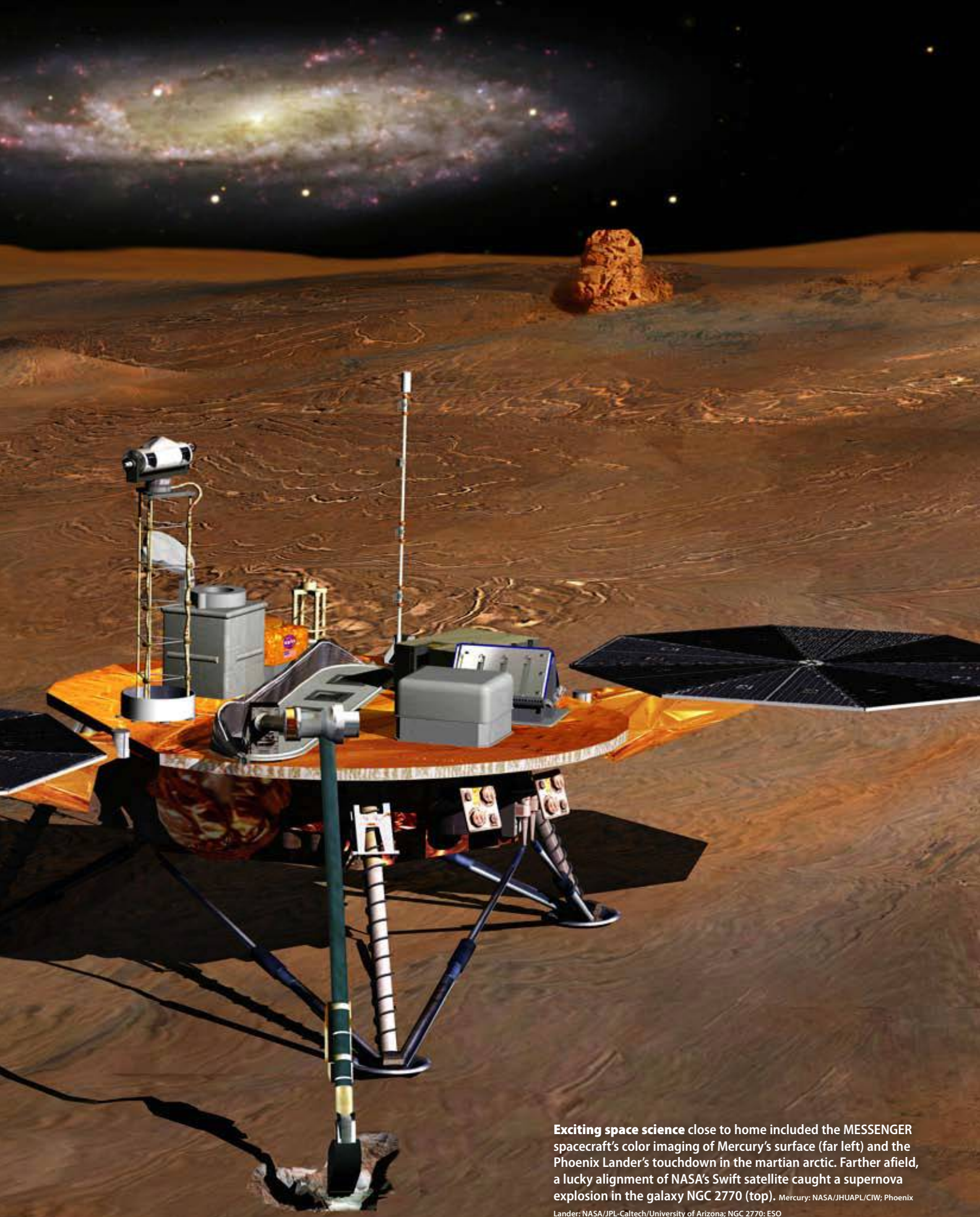
Top 10 stories of 2008

Astronomers saw the first moments of a star's death, the Phoenix Lander tasted martian water, exoplanet hunters discovered a mini version of our solar system, and more.

by Daniel Pendick

The past year brought significant discoveries from the remotest corners of the cosmos as well as our nearest neighbors in the solar system. Astronomers observed the brightest gamma-ray burst ever, finished an important survey of 70 massive galaxies, and, for the first time, watched the start of a supernova. The discovery of strange and unexpected movements of hundreds of galaxy clusters posed challenging new questions about the large-scale structure of the universe.

Scientists also continued to explore the solar system with the touchdown on Mars of a chemistry lab, the Phoenix Lander. The MESSENGER probe swung by Mercury twice for our first close look at that planet in decades. And researchers also revealed the long-sought explanation for what triggers dramatic surges in the aurora called substorms.



Exciting space science close to home included the MESSENGER spacecraft's color imaging of Mercury's surface (far left) and the Phoenix Lander's touchdown in the martian arctic. Farther afield, a lucky alignment of NASA's Swift satellite caught a supernova explosion in the galaxy NGC 2770 (top). Mercury: NASA/JHUAPL/CIW; Phoenix Lander: NASA/JPL-Caltech/University of Arizona; NGC 2770: ESO

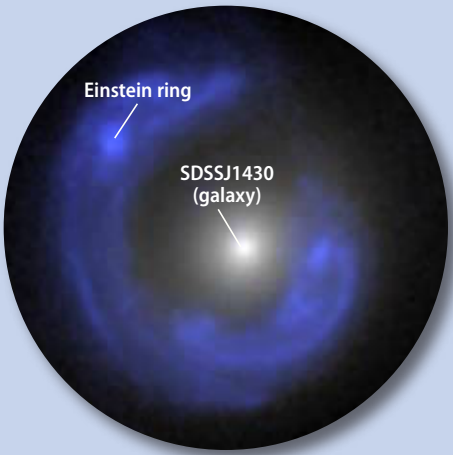
10 Gravity lens survey reaches a milestone

The Sloan Lens Advanced Camera for Surveys (SLACS) project culminated in a powerful new tool: a catalog of 70 "strong" gravitational-lens galaxies. It's the largest single collection of such objects to date.

Astronomers use gravitational lenses to observe distant objects — typically galaxies — that would otherwise be too dim to see. The lensing galaxy's gravity bends the light from the background object inward. From Earth, the more distant object's light appears brighter and forms arc-shaped mirages around the lensing galaxy. If the alignment is just right, a complete "Einstein ring" forms around the lens.

A strong lens is one whose line-of-site alignment with Earth maximizes the lensing effect. A team led by the University of Hawaii's Adam Bolton and Leon Koopman of the Kapteyn Astronomical Institute in The Netherlands compiled a catalog of 70 strong gravitational-lens galaxies along with precise measurements of their distances and masses.

To identify massive elliptical galaxies with potential to be gravitational lenses, the astronomers searched the catalog of the Sloan Digital Sky Survey (SDSS). The Hubble Space Telescope's Advanced Camera for Surveys confirmed the presence of arcs and rings and precisely measured their apparent diameters. SDSS data pinpointed the distances to both the lensing and background galaxies.



The gravitational-lens galaxy SDSSJ1430 magnifies and brightens light from a more distant background galaxy up to 30 times, making it visible to the Hubble Space Telescope as a ghostly "Einstein ring." Adam Bolton (UH/IfA)/SLACS/NASA/ESA

The data allowed Bolton and Koopman's team to measure the masses of the lensing galaxies much more precisely than in past surveys. The SLACS team put its new catalog to work and reported the results August and September in *The Astrophysical Journal*.

The research addressed an old debate about the relationship between mass and brightness in giant elliptical galaxies. Previous studies suggested that as galaxies get more massive, they don't grow proportionately brighter. The new SLACS data confirmed this pattern. Now the question is "why?"

Bolton says the likely answer is that, as galaxies grow, the fraction of their mass consisting of dark matter also increases. (Dark matter is a hypothetical substance that has gravity but does not emit light.) "So galaxies can get more massive without getting brighter by the same amount," he says.

Bolton hopes to search the results of SDSS's third phase, now in progress, for strong lenses further back in cosmic time. These might reveal more about the role of dark matter in galaxy evolution.

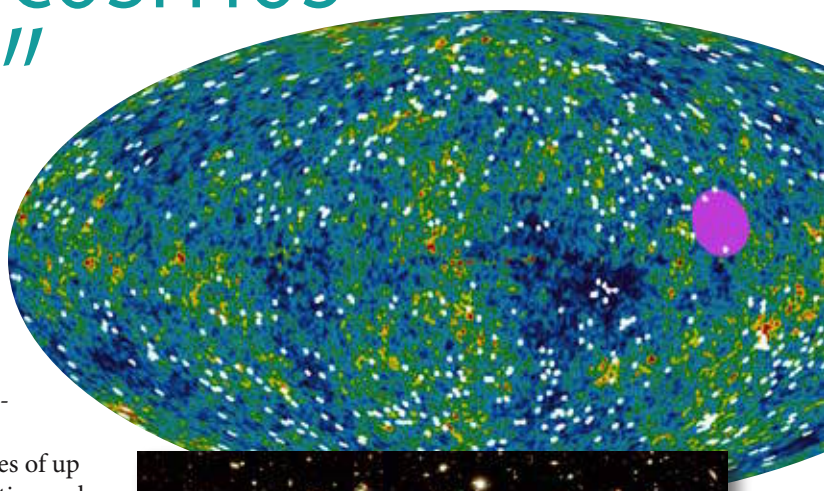
8 Discovered: an alien solar system like home

Astronomers found a solar system analog, a planetary system with scaled-down equivalents of our Jupiter and Saturn. Until now, most exoplanetary systems seemed to follow a radically different blueprint. This included oddities like gaseous "hot Jupiters" orbiting improbably close to their stars rather than in the frigid suburbs, as do gas giants in our solar system.

A team led by Ohio State University astronomer Scott Gaudi found the two

MOA-2007-BLG-192Lb, a 3.3-Earth-mass planet, orbits a dim brown dwarf star in this artist's depiction. Astronomers found the planet using a technique called gravitational microlensing. NASA Exoplanet Exploration Program

9 Seeing the cosmos' "dark flow"



Astronomers discovered a bizarre and unexpected "dark flow" of galaxy clusters possibly extending beyond the observable universe. Astrophysicist Alexander Kashlinsky of Goddard Space Flight Center in Greenbelt, Maryland, and his colleagues announced the surprising finding October 20 in *Astrophysical Journal Letters*. Kashlinsky dubbed the cluster motions dark flow in reference to two other cosmological mysteries — dark energy and dark matter.

The study focused on 700 massive galaxy clusters at distances of up to 6 billion light-years. Kashlinsky's team measured cluster motions relative to the cosmic microwave background (relic radiation from the early universe). The clusters move as a group toward a small patch of sky between the constellations Vela and Centaurus. The flow extends for at least 1 billion light-years — probably farther, Kashlinsky believes.

Nothing exists in the observable universe with gravity strong enough to account for the clusters' motions. One possible cause is a concentration of mass beyond the universe's visible frontiers. Such a mass would be consistent with cosmic inflation theories.

Inflation refers to a brief period of hyper-expansion that occurred when the universe was young. But massive structures could exist beyond the observable cosmos, pushed there by inflation.

Dark flow surprised even the scientists who found it. "We were and still are certainly very puzzled," Kashlinsky says. "It was not the result that we ever expected to measure." The researchers will need strong evidence to convince their colleagues that dark flow is real. Kashlinsky says his team is working to confirm its discovery using a larger sample of galaxies and the latest cosmic microwave background data from NASA's Wilkinson Microwave Anisotropy Probe.

White dots (top image) mark 700 galaxy clusters moving as a group toward the same region of sky (pink oval). Astronomers measured in the flow relative to the cosmic microwave background (CMB), relic radiation from the early universe. Galaxy cluster 1E 0657-56 (above) is one of clusters swept along by this mysterious "dark flow." NASA/WMAP/A. Kashlinsky et al.

planets around a star about 4,900 light-years from Earth. Based on their sizes, both are probably gas giants like Jupiter and Saturn, but with masses 30 and 10 percent smaller, respectively.

Still, the planetary system shares some important traits with our own. For example, the ratio of each planet's mass to that of its host star is similar to the ratios for Jupiter and Saturn. The exo-Saturn is twice as far away from its star as the exo-Jupiter, just as our Saturn orbits the Sun at twice the distance as Jupiter does.

The exoplanets' star is half the Sun's mass and radiates 5 percent of its light. But because the planets orbit closer to their star, their temperatures would still be similar to those of Jupiter and Saturn.

"If we scale everything to the mass and brightness of the parent star, the masses of these planets relative to their star's mass and the amount of sunlight they receive are close to our own Jupiter and Saturn," Gaudi says.

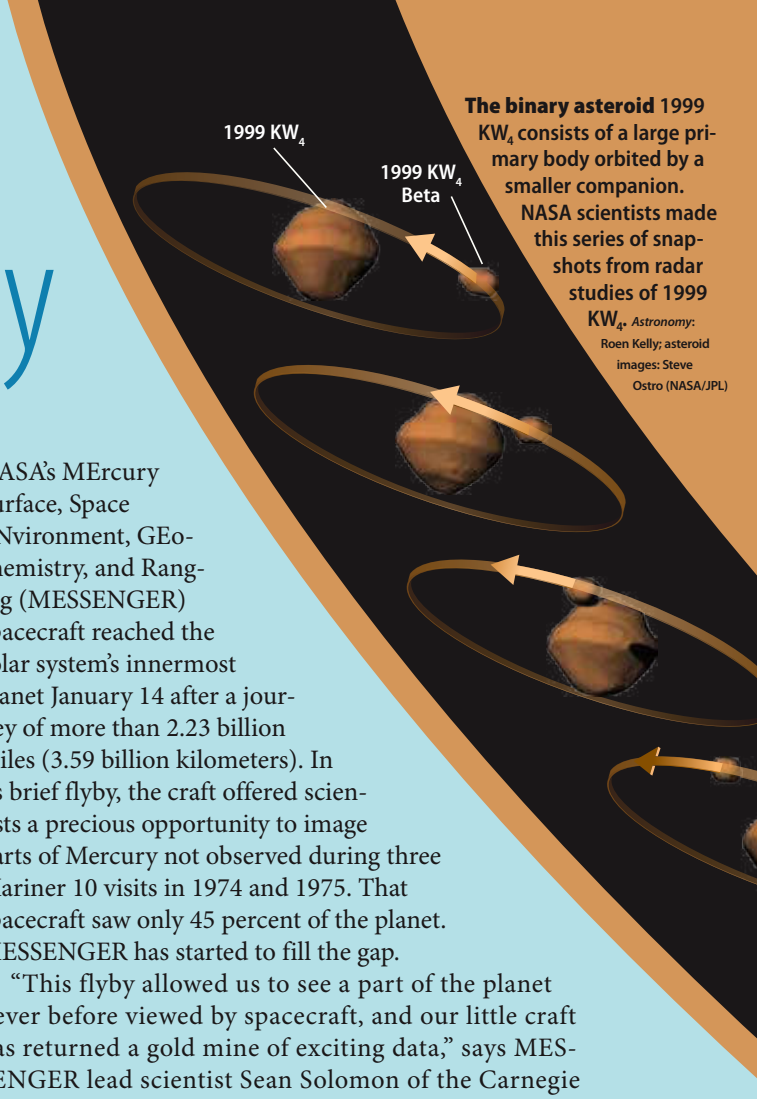
The discovery, published February 15 in *Science*, proved the value to exoplanet studies of a technique called gravitational microlensing. "It's now not just detecting new planets, but providing fundamentally new information about extrasolar planets," Gaudi says. "For example, microlensing has uncovered an entirely new class of planets, cool 'super-Earths,' which were expected theoretically but had not been seen previously."

Microlensing exploits chance alignments between stars. When a star passes in front of a background star, the foreground star's gravity bends the passing light rays inward.

From Earth, this gravitational lensing effect slightly boost's the background star's brightness. If the foreground star also has a planet, it adds a tiny "blip" of light to the general brightening. Calculations based on the blip reveals the planet's mass and distance from its star.

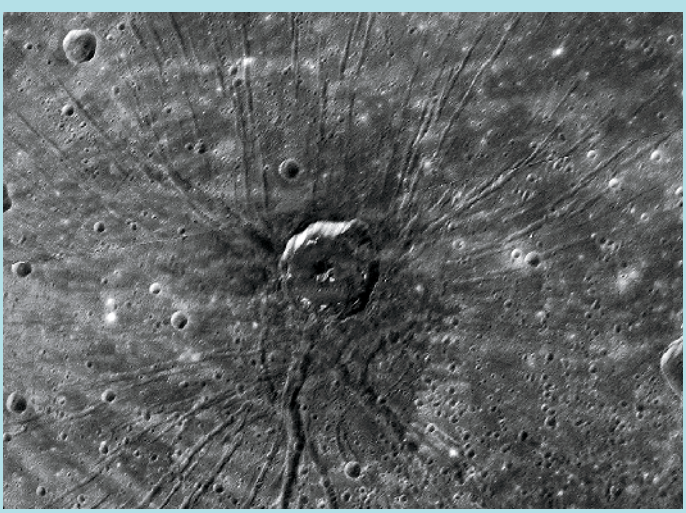
The planets Gaudi's team discovered were only the fifth and sixth detected with gravitational microlensing. Since then, astronomers using the technique have notched two more exoplanets — one of which is a rocky planet of only about 3 times Earth's mass.

7 MESSENGER visits Mercury



The binary asteroid 1999 KW_4 consists of a large primary body orbited by a smaller companion. NASA scientists made this series of snapshots from radar studies of 1999 KW_4. *Astronomy:* Roen Kelly; asteroid images: Steve Ostro (NASA/JPL)

MESSENGER data from its first flyby of Mercury January 2008 revealed the volcanic features (indicated by arrows) that dot the planet's crust. Volcanism has strongly shaped Mercury's surface. NASA/JHUAP/Arizona State University



A mysterious feature, "the Spider," lies within Mercury's Caloris Basin. More than 100 troughs radiate outward from its center. NASA/JHUAPL/CIW

NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft reached the solar system's innermost planet January 14 after a journey of more than 2.23 billion miles (3.59 billion kilometers). In its brief flyby, the craft offered scientists a precious opportunity to image parts of Mercury not observed during three Mariner 10 visits in 1974 and 1975. That spacecraft saw only 45 percent of the planet. MESSENGER has started to fill the gap.

"This flyby allowed us to see a part of the planet never before viewed by spacecraft, and our little craft has returned a gold mine of exciting data," says MESSENGER lead scientist Sean Solomon of the Carnegie Institution of Washington.

The spacecraft revealed new details about the solar system's tiniest planet, such as the strange feature dubbed "the Spider." It lies in the middle of a large impact crater called the Caloris Basin and consists of more than a hundred narrow, flat-floored troughs radiating outward like the spokes in a spider's web.

Scientists have seen nothing like it before on Mercury or any other solar system body. What created it? Solomon suspects the Spider formed after a meteorite impact relieved preexisting crustal stress in the Caloris Basin, triggering the formation of troughs that spread outward like cracks in a windshield.

However, other investigators feel the question of what formed the Spider is still open. "The Spider has a crater near its center, but whether that crater is related to the original formation or came later is not clear at this time," says James Head, a MESSENGER participating scientist at Brown University.

MESSENGER's cameras collected 1,213 images. Other instruments, including a spectrometer, harvested reams of new data on Mercury's surface, hyperthin atmosphere, and magnetic field. Researchers discussed the findings July 4 in *Science,* in 11 reports dedicated to the first flyby.

Mark S. Robinson of Arizona State University and 12 colleagues released observations of Mercury's surface by MESSENGER's multispectral imaging instrument. The new data revealed lava flows, craters, and other unmistakable signs of the extent to which volcanic activity has transformed the surface of the solar system's smallest planet.

6 How light creates binary asteroids

Astronomers took another step toward understanding the complex and diverse behavior of asteroids — rocky bodies that wander the interplanetary spaces of our solar system. It turns out that something as mundane as sunlight striking the surface of these solar system wanderers explains changes in asteroid spin and how they evolve into binary pairs.

The key process at work is the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect, named after the four scientists whose work contributed to the modern understanding of light's fundamental influence on the motions of asteroids.

The YORP effect occurs when asteroids absorb sunlight. Part of the energy escapes back into space as photons of infrared light. As the photons zip away from an asteroid's uneven surface, they exert a tiny recoil force.

Over time, the recoil's effect can significantly speed up or slow down an asteroid's spin, depending on the angle at which sunlight strikes the rock and its shape and orientation. The effect of sunlight on asteroids can even change their orbits around the Sun.

Astronomers reported July 10 in *Nature* that YORP powers the creation of many binary asteroids. They travel as pairs of co-orbiting bodies, typically a large primary asteroid with a smaller companion. Binaries make up about 15 percent of the asteroids less than 6 miles (10 kilometers) in diameter. Astronomers find them in two populations. Some, called near-Earth asteroids (NEAs), orbit relatively close to Earth. The remainder lie within the more populous "main belt" between Mars and Jupiter.

In the *Nature* report, Kevin Walsh of Cote d'Azur Observatory in France and two colleagues described a computer simulation they created to find out if YORP-induced spin could have transformed the "rubble pile" asteroid 1999 KW_4 into a binary. Rubbly asteroids consist of many smaller chunks held together by mutual gravitational attraction.

The primary member of binary asteroid 1999 KW_4 is about 0.9 mile (1.5 km) across and sports a prominent ridge on its equator where spin is causing rubble chunks to accumulate. The secondary asteroid, 1999 KW_4 Beta, is about 0.3 mile (0.5 km) across and circles its companion every 16 hours at a distance of 1.6 miles (2.6 km).

In the computer runs, the initially intact rubble pile asteroid spins up and starts to throw off bits of debris. Loose material at the poles tends to roll over the asteroid's surface to the equator. Meanwhile, the tiny bits of debris clump into a larger body and eventually form a satellite. The whole process takes hundreds of thousands of years.

The computer simulations make a strong case that the YORP effect shapes rubble-pile asteroids into binaries. If that's true, it also implies that many asteroids orbiting near Earth are unstable rubble piles. That concerns planetary defense experts, because it could be much more challenging to deflect an Earth-bound rubble pile than a solid rock.

MESSENGER looped in for another flyby October 6. After a third and final flyby in September 2009, the probe will finally slip into orbit — in 2011.

By exploring Mercury, we may also learn something about our own world. "Planetary science is much about comparisons," wrote Brooks Hanson, an editor at *Science*, in a commentary on the January flyby. "Studying other bodies in our solar system with different sizes and compositions provides essential context for understanding Earth's formation and evolution."

Mission scientists stressed that the first two flybys are just the beginning of Mercury's exploration. "We are just getting started to go where no one has been before," says MESSENGER scientist Ralph McNutt of the Johns Hopkins University Applied Physics Laboratory.

5 Fermi blasts off

There's a new astrophysical observatory in the neighborhood: the Fermi Gamma-ray Space Telescope. The satellite launched without a hitch June 11 and began to explore the universe in high-energy gamma rays. Once the observatory, formerly known as GLAST, was operational, NASA named it in honor of high-energy physics pioneer Enrico Fermi (1901–1954).

Fermi carries two instruments, the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). Together, the LAT and GBM can observe the widest range of gamma-ray emissions of any spacecraft to date. Gamma rays are the most energetic form of electromagnetic radiation.

The GBM instrument detects gamma-ray bursts (GRBs), powerful explosions triggered by the collapse of massive suns or the merger of neutron stars. The LAT scans the entire sky every 3 hours in survey mode.

On August 26, NASA released an all-sky image that shows what Fermi can do. In the image, gas and dust in the Milky Way's disk glow in gamma rays. The emissions come from collisions between the disk material and cosmic rays.

The map also shows three pulsars, which are rapidly rotating neutron stars formed in the collapse of massive stars. Astronomers originally found the Crab Nebula and Vela pulsars because of their prominent radio emissions.

In contrast, the third pulsing energy source on Fermi's map, the Geminga pulsar, is not a radio source. Fermi should find many more radio-quiet pulsars and perhaps help scientists better understand these unusual objects.

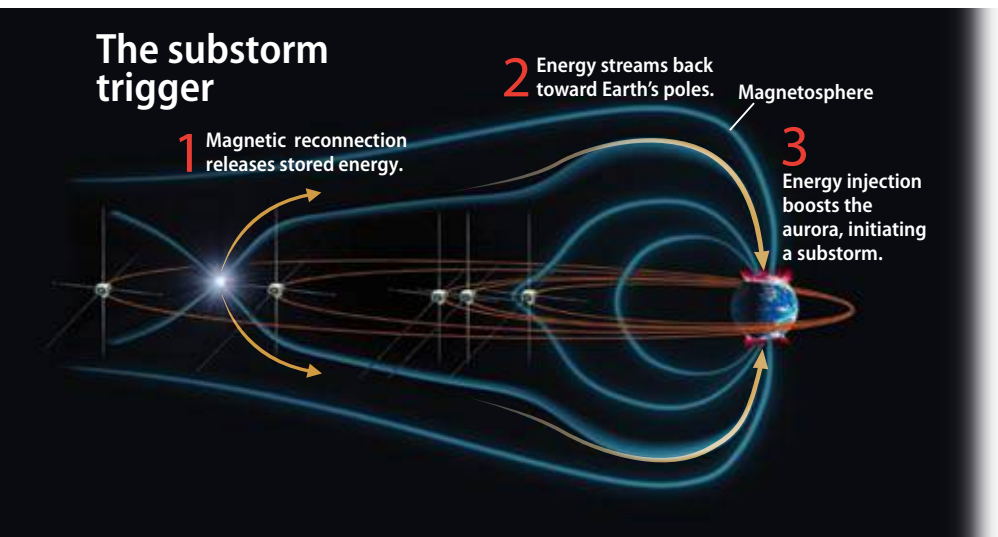
Fermi's early look also spotted a blazar, a type of highly active galaxy that undergoes dramatic flare-ups. Called 3C 454.3, the blazar is now in the middle of an outburst.

Fermi opens up a new view on some of the most energetic events in the universe. In its first month of operations, the satellite spotted 31 gamma-ray bursts, or about one per day. Stay tuned for more updates from the gamma-ray universe.

4 What powers auroral storms

A fleet of NASA spacecraft solved the greatest outstanding mystery of the northern and southern lights: the origin of sudden, explosive flare-ups called auroral substorms. Scientists knew substorms release energy trapped in Earth's magnetic field. However, the critical details of how and where the energy is released have remained controversial. To settle the question, NASA launched five identical spacecraft into orbit in February 2007 on the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission.

Every 4 days, the satellites lined up along Earth's magnetosphere — the volume of space under the influence of the planet's magnetic field. The satellites monitored electrical and magnetic fields and charged particles.


The substorm trigger
1 Magnetic reconnection releases stored energy.
2 Energy streams back toward Earth's poles.
Magnetosphere
3 Energy injection boosts the aurora, initiating a substorm.

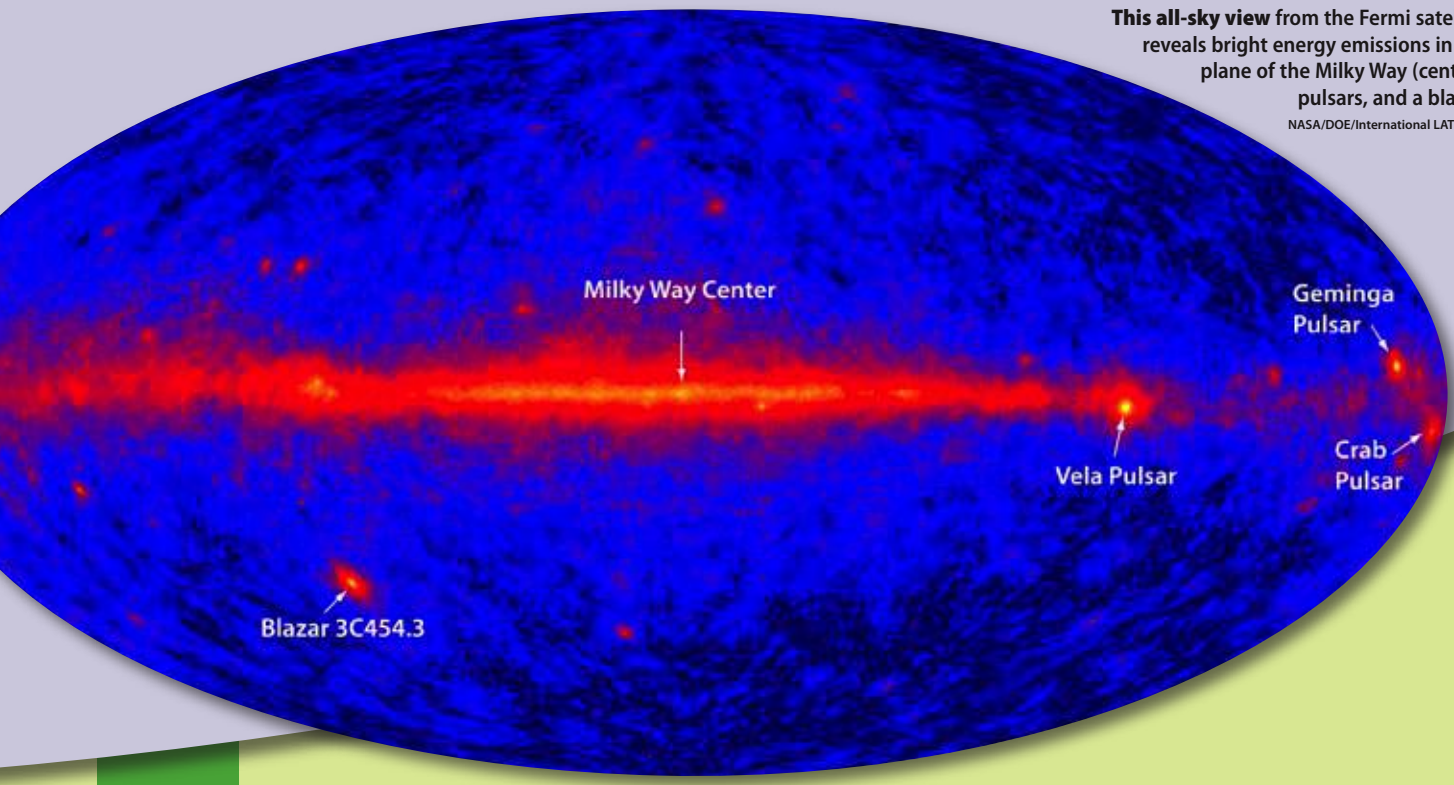
On February 26, 2008, the THEMIS dragnet caught a substorm, providing researchers the data they needed. "We discovered what makes the northern lights dance," says UCLA's Vassilis Angelopoulos, lead scientist for THEMIS.

The power source for substorms is magnetic reconnection. The "solar wind" of charged particles from the Sun flows around Earth's magnetosphere. This squeezes and compresses the magnetic field, storing energy.

When the lines of magnetic force can stretch no farther, they snap and reconnect to form U-shaped loops that channel energy toward Earth's poles. This injection temporarily supercharges the aurora. The critical event — magnetic reconnection — occurs about a third to a half of the distance to the Moon's orbit, the team reported August 14 in *Science*.

THEMIS data will help scientists build more accurate models of substorms and other aspects of "space weather." Major space storms can disrupt earthly communications and even damage satellites.

THEMIS spacecraft line up at midnight over North America every 4 days. Several of the satellites caught the triggering event for an auroral substorm February 26, 2008. The satellites confirmed that a process called magnetic reconnection powers auroral substorms. NASA



This all-sky view from the Fermi satellite reveals bright energy emissions in the plane of the Milky Way (center), pulsars, and a blazar. NASA/DOE/International LAT Team

3 Brightest blast ever observed

A powerful gamma-ray burst (GRB) detected March 19 by NASA's Swift satellite has smashed the record for the brightest blast ever seen. Astronomers around the world trained a variety of telescopes on the burst, formally known as GRB 080319B. Quick action — and a bit of luck — gave astronomers the most detailed view of a GRB to date.

Most GRBs occur when a massive star runs out of nuclear fuel and collapses, forming a black hole. Jets of material erupt from the star at near light-speed. An intense burst of radiation, from gamma rays to visible light, accompanies the jets. After the initial blast, a fading afterglow may persist for months.

A number of instruments besides Swift observed GRB 080319B at various times and at a variety of wavelengths. This included NASA's Wind satellite and several ground-based telescopes. Luckily, some of the instruments just happened to be pointed in the right direction to witness the burst before, during, and after it went off.

These lucky breaks allowed astronomers to capture the optical emission and gamma-ray flashes of a GRB simultaneously for the first time. Within 15 seconds, the explosion brightened to a peak magnitude of 5.3 on the astronomical brightness scale and then began to fade after about 40 seconds. Despite the fact that GRB 080319B lay 7.5 billion

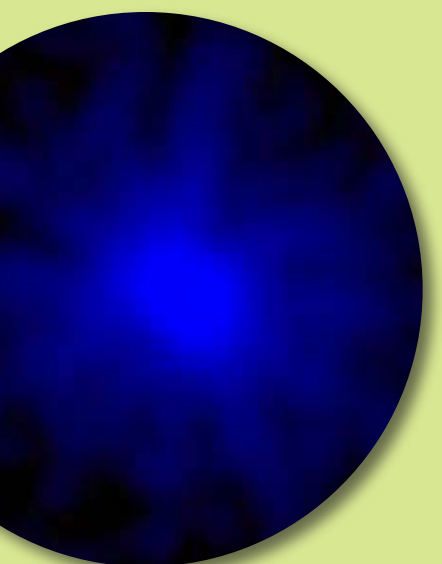
Briefly visible to the naked eye, GRB 080319B was the brightest gamma-ray burst ever seen. Observations suggest energy beamed outward in two nested cones, as shown in this artist's concept. NASA/Swift/Mary Pat Hrybyk-Keith and John Jones

light-years from Earth, its glow was briefly visible to the naked eye.

In the months after the event, astronomers sifted through the observations of GRB 080319B, trying to explain its exceptional brightness. A team led by Pennsylvania State University astronomer Judith Racusin determined that GRB 080319B had two-zoned jets.

Racusin and her colleagues propose that the inner and most intense zone of one jet was pointed almost directly at Earth, like the barrel of a shotgun. In previous GRBs, we might have viewed the weaker and wider portion of a jet. The team reported its findings September 11 in *Nature*.

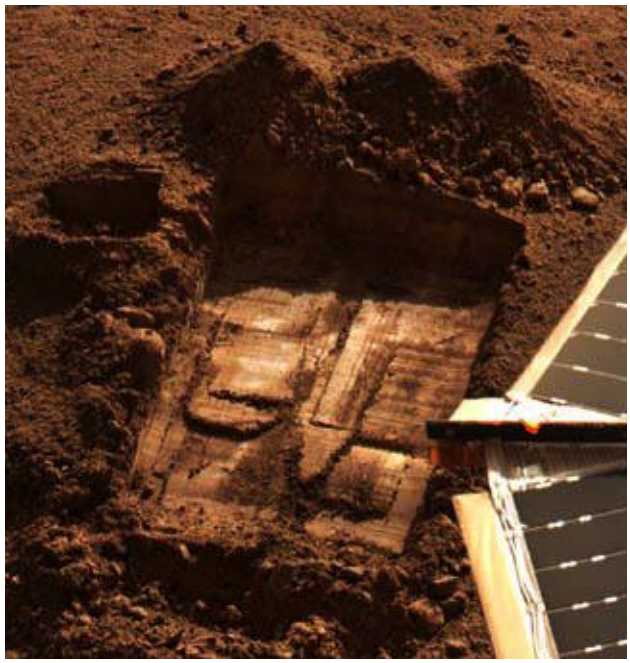
"Maybe every gamma-ray burst contains a narrow jet, too, but astronomers miss them because we don't see the jet head-on," Racusin says. Statistically, astronomers should see one such dead-on GRB per decade.



NASA's Swift satellite imaged GRB 080319B with its X-ray telescope, producing this vivid starburst image. The event set a record for the brightest gamma-ray burst ever seen. NASA/Swift/Stefan Immler

2 Phoenix gets the dirt on Mars

Planetary scientists got their first direct taste of water and organic molecules in the martian soil, thanks to the miniature chemistry lab aboard NASA's Mars Phoenix Lander. After the craft touched down May 25, its robotic arm scooped the first of a series of sampling trenches to expose hard, icy soil. After some initial difficulty scraping out a sample of frozen soil, scientists started to get their first data.



The Phoenix Lander's mechanical arm scraped a soil sample from this trench, dubbed Snow White, and delivered it to its onboard laboratory for tests. NASA/JPL-Caltech/University of Arizona/Texas A&M University

Phoenix confirmed the presence of water in the martian soil beyond doubt. "We've seen evidence for this water ice before in observations by the Mars Odyssey orbiter and in melting chunks observed by Phoenix last month, but this is the first time martian water has been touched and tasted," says William Boynton of the University of Arizona.

Performing this feat at a distance of 171 million miles (275 million kilometers) was a challenge. Boynton and his team developed the Thermal and Evolved Gas Analyzer (TEGA), a multifunctional laboratory with eight separate ovens. (Each oven is about the size of the ink cartridge in a ballpoint pen.) A heater brings the samples up to 1832° Fahrenheit (1000° Celsius) to drive off molecules for identification by a miniature mass spectrometer.

But it was Phoenix's Microscopy, Electrochemistry, and Conductivity Analyzer (MECA) instrument package that achieved one of the mission's most important finds. MECA mixes soil samples with a water-based solution for "wet chemistry." Inside the instrument's mixing chambers, 26 electronic sensors provide clues as to the chemicals present in the soil.

MECA found evidence of a chemical called perchlorate in multiple soil samples. Perchlorate is a charged molecule, or ion, consisting of one chlorine atom surrounded by four of oxygen. Being an oxidant, perchlorate can release its oxygen atoms in certain chemical reactions. Naturally, scientists are intrigued by what the presence of perchlorate means for martian soil chemistry and its potential to support life.

Oxidants can be supportive of life or harmful to it — it depends on the circumstances and chemical reaction involved. Perchlorate is an ingredient in fireworks and rocket fuel, but the same chemical can also sustain certain terrestrial microbes. "It does not preclude life on Mars," Boynton says. "In fact, it is a potential energy source."

After the initial finding, mission scientists worked hard to confirm it with independent data from TEGA and also to rule out the possibility that contamination of the Lander with material from Earth could explain MECA's results.

NASA scientists get another crack at the Red Planet with the roving Mars Science Laboratory, slated for launch in 2009.

1 Astronomers hear a star's death gasp for the first time

Astronomers have seen plenty of supernovae, the rapidly expanding remnants of exploded stars. But in 2008 they got their first glimpse of a star in the first moments of its destruction.

Supernova 2008D burst to life January 9 in the spiral galaxy NGC 2770, about 88 million light-years from Earth. At the same time, Princeton astronomer Alicia Soderberg was conducting observations with NASA's Swift satellite of another supernova, SN 2007uy, that had ignited 10 days earlier.

While collecting data for Soderberg on SN 2007uy, Swift's X-ray Telescope (XRT) also caught SN 2008D in the same field of view — an extraordinary coincidence. "I truly won the astronomy lottery," Soderberg says.

Swift's instruments captured an intense outburst of X rays lasting about 400 seconds. This, Soderberg realized, might be a supernova breakout event — the first gasp of a dying star long predicted but not yet observed.

Theory said that after a massive star runs low on fuel and collapses under its own gravity, a shock wave radiates outward from the core at 70 percent of light-speed and blows the star to bits. This violent process generates an intense X-ray flash lasting seconds to minutes.

Daniel Pendick *is an associate editor of* Astronomy.

Soderberg promptly alerted the astronomical community. In less than 2 days, the 8-meter Gemini North Telescope in Mauna Kea, Hawaii, had confirmed Swift's supernova detection.

SN 2008D confirmed the supernova breakout theory. But it also showed that astronomers can use the X-ray flash to detect supernovae and train instruments on them quickly.

Some supernovae don't peak in visible light for as long as a month. The event goes undetected until all the early fireworks are long over. But those early moments may hold the key to understanding supernovae in greater depth.

Future wide-field X-ray satellites that could monitor most of the sky simultaneously are already planned. One under serious consideration, Soderberg says, is the Energetic X-ray Imaging Survey Telescope (EXIST).

EXIST or a satellite like it could detect hundreds of supernovae per year, Soderberg says. Astronomers could begin observing sooner with a wider range of instruments.

It remains unclear what drives the shock wave. Thanks to SN 2008D, astronomers can now lobby for the new all-sky X-ray observatories needed to catch more supernovae in the act of exploding. These would provide the data needed to develop and confirm theories of what drives the death of a star.

Italy's Asiago Observatory captured this image January 12, 2008, of two supernovae visible simultaneously in the galaxy NGC 2770. ESO

Watch for these headlines in 2009

IYA2009, the International Year of Astronomy 2009, begins January 1. The global celebration aims to stimulate greater interest in astronomy and science.

NASA's Dawn spacecraft flies by Mars in February for a gravity boost en route to its rendezvous with asteroids Vesta in 2011 and Ceres in 2015.

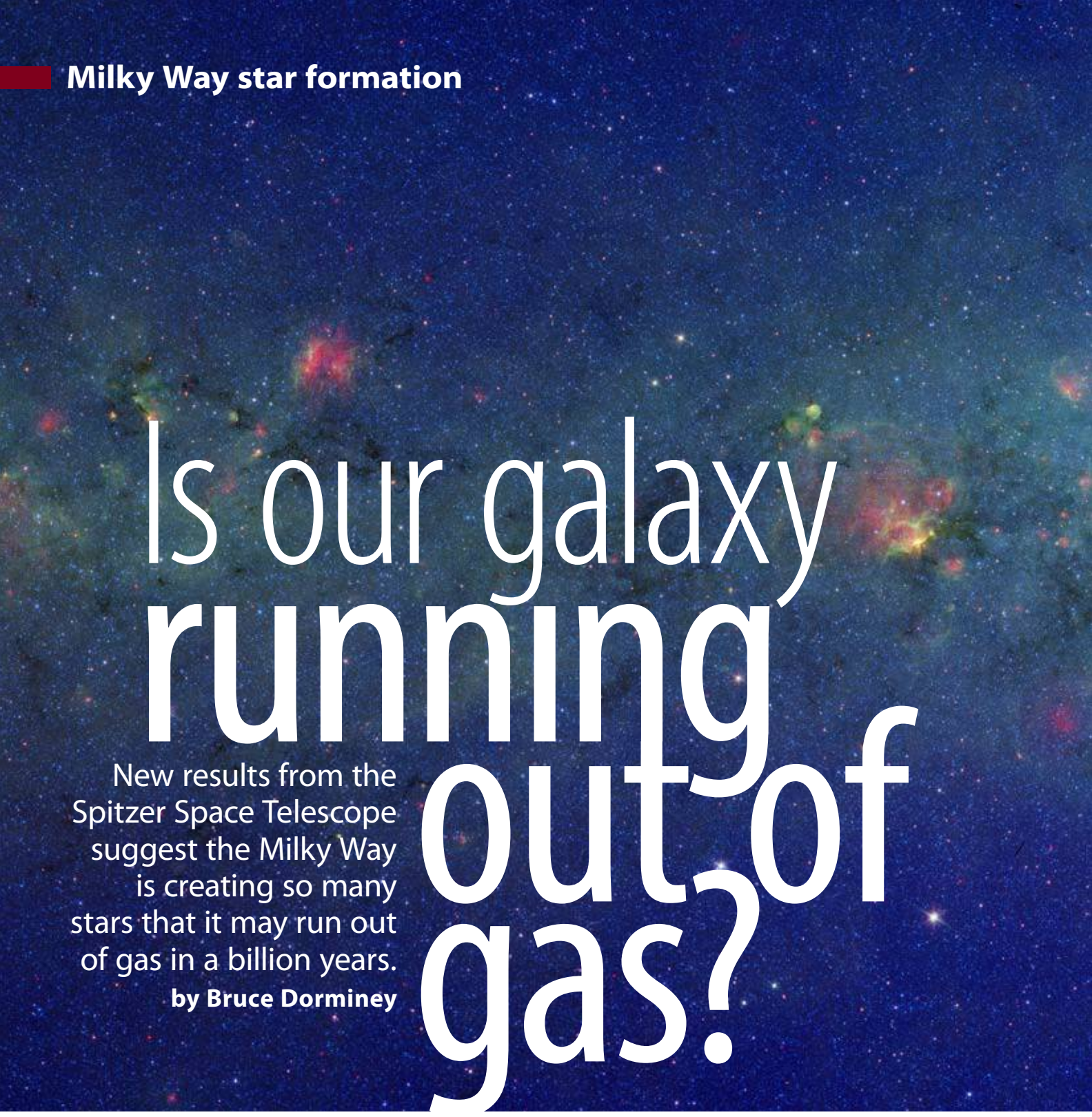
NASA will launch Ares I-X, a test prototype of the Ares I launch vehicle. The rocket will carry an unpiloted mock-up of Orion, the successor to the space shuttle.

NASA's Kepler satellite will search for extrasolar planets the size of Earth and smaller. Launch is set for June.

MSL, the Mars Science Laboratory, is scheduled to launch in September to assess the martian soil's past or present suitability for life.

The Hubble Space Telescope will get its fifth and final round of repairs and upgrades by space shuttle astronauts.

To learn more about astronomy and space events coming in 2009, go to www.Astronomy.com/toc.



Is our galaxy running out of gas?

New results from the Spitzer Space Telescope suggest the Milky Way is creating so many stars that it may run out of gas in a billion years.

by Bruce Dorminey

To the most casual observer, the night sky gives the impression that it hasn't changed since time immemorial. A closer look, however, reveals the Milky Way Galaxy's ongoing cycles of cosmic death and rebirth.

The plane of our Milky Way is chock full of star-forming regions. Astronomers estimate that, all told, those regions add some 5 solar masses of new stars to the galaxy per year. But that figure may soon have to be ratcheted up.

Of the approximately 6,000 stars visible to the naked eye on a dark night, most have significantly more mass than the Sun and are intrinsically luminous. These high-mass stars live fast and die young, exploding as supernovae less than 50 million years after their births.

Yet the vast majority of the Milky Way's estimated 400 billion stars are middle-aged or older and have less mass than the Sun. These cool, reddish stars don't radiate much visible light. Instead, they generate invisible infrared radiation (heat). So, to

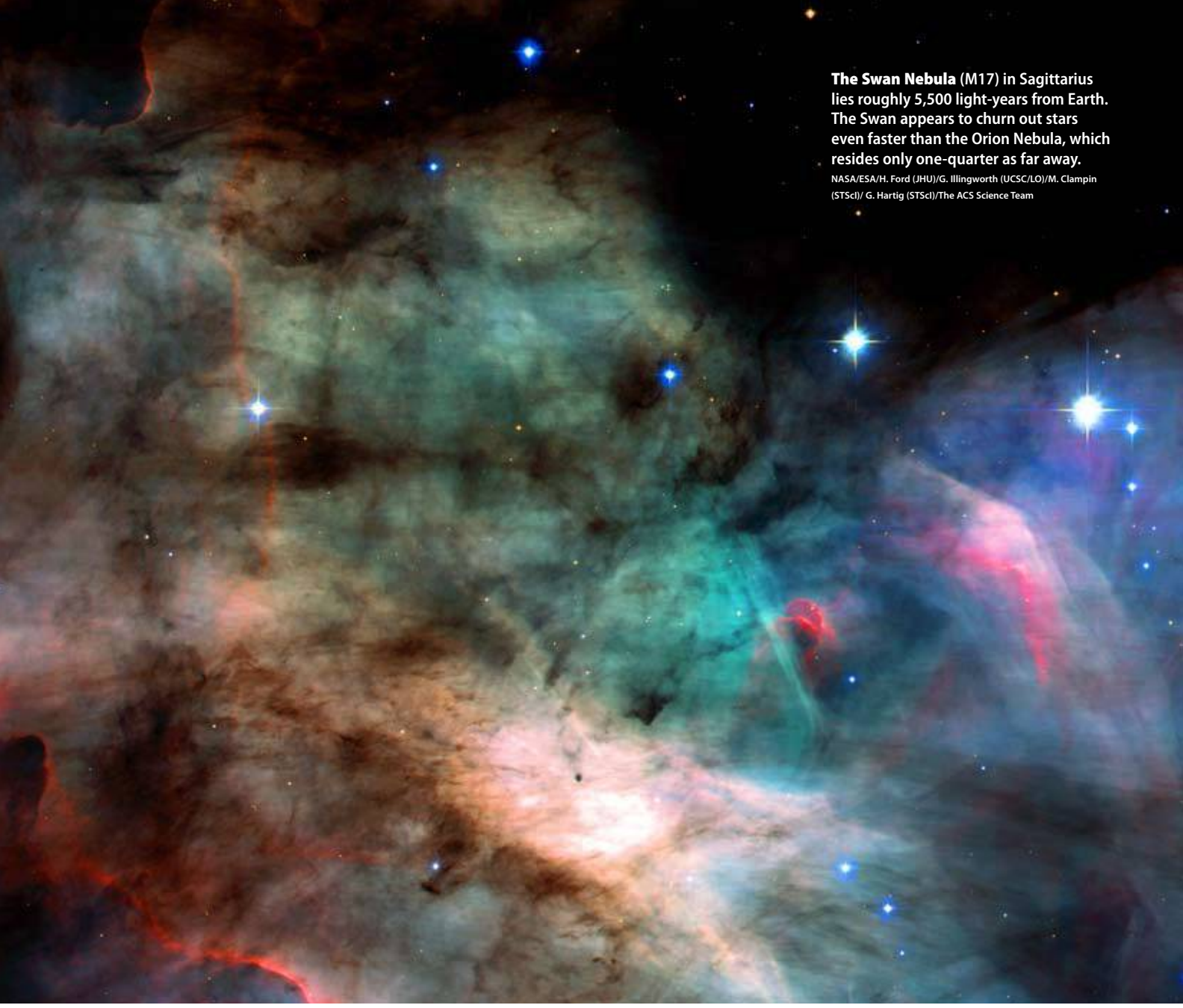
The galaxy's center dominates this view from the Spitzer Space Telescope. Two complementary Spitzer surveys reveal that the Milky Way produces stars at a faster pace than astronomers previously thought.
NASA/JPL-Caltech/ University of Wisconsin

learn the details of Milky Way star formation, astronomers need to expand their vision beyond the visible.

That's just what they've done. Researchers used NASA's infrared-sensitive Spitzer Space Telescope to take the infrared heartbeat of our galaxy. Results from the observatory's two complementary surveys have started to change scientists' view of star formation in the Milky Way. Early results hint that the galaxy's current frenzy of star birth can't be sustained for more than a billion years.

The galaxy's infrared pulse

The Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) and the Multiband Imaging Photometer for Spitzer Inner Galactic Plane Survey (MIPSGAL) are the most sensitive and highest resolution infrared maps of the galactic plane yet. And Caltech's Sean Carey, MIPSGAL's principal investigator, claims they will remain the best large-scale maps for the foreseeable future. That's because no project combining such sensitivity and wide-angle views is in the cards for more than a decade.



The Swan Nebula (M17) in Sagittarius lies roughly 5,500 light-years from Earth. The Swan appears to churn out stars even faster than the Orion Nebula, which resides only one-quarter as far away.
NASA/ESA/H. Ford (JHU)/G. Illingworth (UCSC/LO)/M. Clampin (STScI)/ G. Hartig (STScI)/The ACS Science Team

The surveys extend 1° above and below the galactic plane and stretch 65° on each side of the galaxy's center. They map out the near- and mid-infrared realms of the galaxy from the central galactic bulge to the spiral arms.

"The large majority of the stars [surveyed by] GLIMPSE have never been cataloged," says Ed Churchwell, GLIMPSE principal investigator and an astronomer at the University of Wisconsin-Madison. "Many were included in the near-infrared 2MASS catalog, which we cross-referenced. But, even in the near infrared, dust limits the number of stars detected. So, not all the 110 million stars in the GLIMPSE catalog are newly detected, but a large fraction are."

Prior to Spitzer's launch, the standard estimate for the number of star-forming regions in the galaxy was somewhere between 5,000 and 7,000. Based on the new data, astronomers may have to double that number. Preliminary results show the number could be between 10,000 and 15,000.

GLIMPSE also cataloged stellar bubbles, stellar outflows, and protostars. MIPSGAL, which observed cooler targets than GLIMPSE, viewed warm dust inside star-forming regions and stars just at the point of formation. MIPSGAL also targeted stars at the tail ends of their lives when they become bloated and start losing mass, creating dusty shells.

Orion — not as big as you think

Among other things, both surveys confirmed that the Orion Nebula (M42), the most studied star-forming region in the sky, is a wimp in comparison to some more distant regions. The activity in the Swan Nebula (M17), the Carina Nebula, or RCW 49 dwarfs that in Orion. Clusters within any given star-forming region can contain anywhere from a few hundred to a few thousand stars, most of which will forever remain binary systems.

Bruce Dorminey *is the author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Copernicus Books, 2001). His most recent* Astronomy *article was "Europe's space revolution" in September 2008.*

Star-forming region RCW 49 ranks among the Milky Way's most prolific sites of star birth. This infrared image reveals hundreds of stars invisible at optical wavelengths. RCW 49 lies in Centaurus some 13,700 light-years from Earth. NASA/JPL-Caltech/E. Churchwell (University of Wisconsin)

The Carina Nebula (NGC 3372) lies some 10,000 light-years from Earth. This infrared image shows the nebula's south pillar region and reveals lots of new stellar embryos (colored yellow and white) tucked inside the dust-rich nebulosity. NASA/JPL-Caltech/N. Smith (University of Arizona)

"We've uncovered a huge amount of star formation that has not been seen before, and star formation happening everywhere and more widely distributed than we realized," says Matthew Povich, Churchwell's doctoral student at the University of Wisconsin-Madison. "M17, in Sagittarius, is actually a monster star-forming region. It contains a very massive cluster with several of the most luminous young stars in the galaxy. As M17 shows, star formation occurs in multiple generations, and it's often difficult to tell the generations apart."

This uncertainty can make things particularly confusing when astronomers try to calculate whether the rate of star formation in the galaxy is indeed higher than current estimates. However, Churchwell says that the first impressions from GLIMPSE suggest the galactic star-formation rate may need to be ramped up significantly.

"We have estimated the star-formation rate of M17 and found that it is about 0.008 solar mass per year — far above [the Milky Way] average," says Povich. Although Povich's Ph.D. thesis will deal with star-formation rates in several large star-forming complexes, he readily admits it will not provide the galaxy's latest global rate. Because of the scale and complexity, Povich says, the quest for such a new figure is turning into a long-range project.

The Orion Nebula (M42) appears spectacular from Earth, but that's largely because it's so close. Other star-forming regions in our galaxy dwarf M42. NASA/JPL-Caltech /T. Megeath (University of Toledo) and M. Robberto (STScI)

Even so, Churchwell says, the bulk of the galaxy's star formation goes on some 10,000 to 30,000 light-years from the galaxy's center. The Sun resides about 26,000 light-years from the galactic center, roughly halfway between the Scutum-Centaurus and the Perseus spiral arms.

At this distance, interstellar matter is roughly equal parts atomic and molecular. Beyond this distance, atomic hydrogen dominates the interstellar environment. Star formation starts to fall off rapidly beyond the Sun's galactic orbit.

The center of it all

Still, as Churchwell notes, some of the galaxy's most massive star-forming regions lie close to the galactic center. The Arches Cluster, for example, formed within a few hundred light-years or so of Sag A* (pronounced "A-star"), the supermassive black hole at the galaxy's center.

"Spitzer surveyed the galactic center, but it's so bright that we can't tell too much about those clusters," says Churchwell. "They must have formed recently because they have massive stars. But [the molecular clouds from which they formed] are rotating several times faster than the outer spiral arms. It's hard to understand how you can get enough matter together to actually form those stars."

Churchwell is referring to the process of star formation, which starts when a dense molecular cloud fragments into smaller pieces and those pieces subsequently accrete material from their surroundings. He notes that a young star's luminosity creates a stellar wind that makes it difficult for the star to accrete more gas. "When material falls toward the star's center of gravity, it also has some rotational motion to it," says Churchwell. "It doesn't just fall radially toward the center of the star, but spirals in."

This creates a centrifugal barrier that keeps matter from getting closer to the star. One way a young protostar can overcome such a barrier is by channeling matter into a bipolar outflow, in which gaseous jets shoot out in opposite directions from the protostar's poles. This allows some of the infalling

The developing Sun-like star L1157 in Cepheus appears to be only a few thousand years old. Typical of such youngsters, the star emits two oppositely directed jets and has a dusty, flattened envelope where planets might one day form. L1157 lies behind lots of opaque dust, so it appears only in infrared light. NASA/JPL-Caltech/UIUC

stellar matter to move into the accretion disk and onto the star. Such a disk probably feeds the surface of the star and afterward may provide enough material to make planets.

Even so, large-scale density waves likely trigger the vast majority of the galaxy's star formation. These density waves pass through any giant molecular cloud (GMC) as it enters a spiral arm. As astronomer Mark Reid of the Harvard-Smithsonian Center for Astrophysics points out, this happens because the spiral arms rotate roughly half as fast as the galaxy as a whole.

From clouds to stars

Orion's star-forming regions have produced thousands of stars in the last 10 million years alone. Such regions, with diameters

Bipolar outflows stream from two young stellar objects forming at the tips of dusty pillars in the Carina Nebula. Such outflows appear to be common among stars being born. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

ranging from 60 to 300 light-years and masses of up to a million Suns, rank among the galaxy's largest structures.

Most of the massive O- and B-type stars form in GMCs. Gravity typically binds these stars to their natal clouds at the beginnings of their lives. But as these massive stars light up, their ultraviolet radiation helps dissipate the gas from which they formed. The massive stars soon get thrown out of the nest, thanks to the GMC's internal dynamics. Orion's Betelgeuse already is in a virtual road race, having traveled some 150 light-years since being born 10 million years ago.

"Most star clusters in the plane of the galaxy are not going to survive terribly long because they are not bound," says Churchwell. "Over time, the stars are going to go in various directions."

To form, a GMC must first accumulate gas over distances of hundreds, or even thousands, of light-years. This can take an estimated 20 million years to complete. Such GMCs maintain their "equilibrium" because supersonic turbulence and magnetic fields within the clouds counterbalance the contracting force of gravity.

But once a cloud reaches a supercritical state, it begins to fragment into dense star-forming cores. This can be triggered by the expanding shell of a supernova, a spiral density wave, a stellar bubble expanding from a massive O or B star, or simply the dissipation of the cloud's turbulence and magnetic forces.

As one of these dense cores grows, its temperature rises to the point where molecular hydrogen dissociates into individual atoms. The core becomes gravitationally unstable and collapses, which marks the beginning of a young stellar object (YSO). As gravitational contraction heats these YSOs, they first burn the hydrogen isotope deuterium.

To become an "official" star, the YSO must derive its energy from hydrogen fusion. For this nuclear burning to take place, a star's core temperature has to hit about 10 million kelvins.

"It's remarkable that, even though the physical conditions in which stars form are different by orders of magnitude, the

outcome seems to be remarkably similar," says Christopher McKee, an astrophysicist at the University of California at Berkeley. "Normally, when you change the initial conditions, that changes the output."

As McKee indicates, one nagging star formation conundrum has been in figuring out how environmental influences affect a given star's size at birth. Far from being a mere curiosity, such knowledge would provide theorists with a tool to link galactic and stellar evolution, while also constraining how much of the universe is made of ordinary matter.

Stellar objects with masses less than 0.08 solar mass cannot produce temperatures hot enough to fuse hydrogen. Such objects fall in the domain of brown dwarfs, or "failed stars." At the other extreme, objects containing more than about 150 solar masses should be too unstable to survive. Such an object would be so hot that the energy it generated would overwhelm the gravitational force holding it together. Observational evidence suggests the average star's mass in our galaxy is about half that of the Sun.

"Astronomers believe most stars form by gravitational collapse of dense cores within molecular clouds," says Patrick Hennebelle, an astrophysicist at Paris Observatory. "The question is what fraction of the mass within one core ends up as a single star? And does one core form a unique star or a small cluster? Observationally, it has been inferred that stellar masses are inherited from the physical mechanisms occurring within molecular clouds."

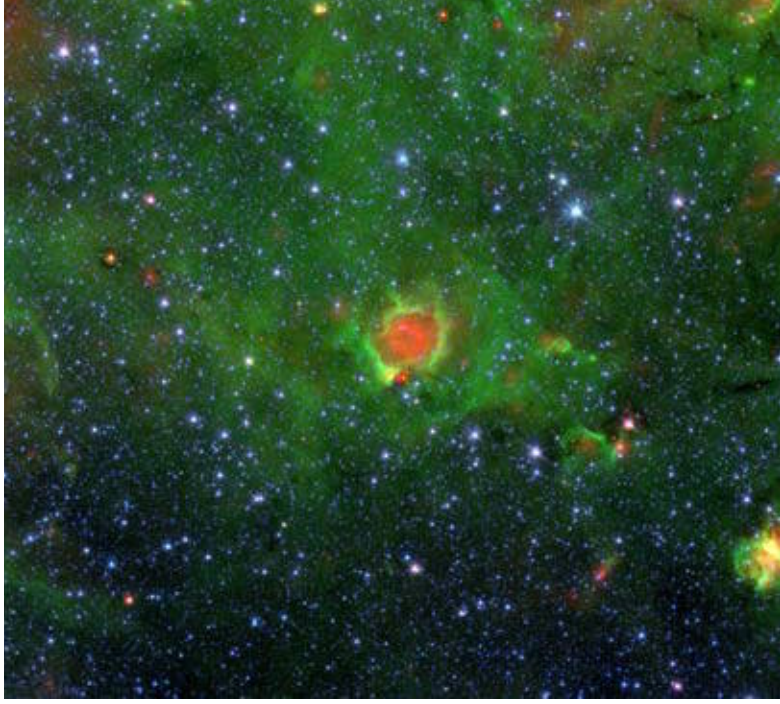
Starting a second generation

Even though the GLIMPSE team can only speculate about the details of complex global dynamics within giant molecular clouds, it has confirmed a new triggering mechanism for follow-on star formation. The process starts with massive O- and B-type stars and their expanding bubbles of hot gas. Astronomers estimate that our galaxy has some 20,000 of these high-mass stars.

GLIMPSE cataloged 591 such stellar bubbles, which act as spherical pistons to compress the surrounding gas and initiate follow-on star formation. So far, Spitzer has found several YSO candidates whose formation likely was triggered by these expanding bubbles.

The Arches Cluster lies within a few hundred light-years of our galaxy's center. Astronomers aren't sure how the Milky Way managed to bring enough material together to form the Arches — the galaxy's densest star cluster. NASA/ESA/D. Figer (STScI)

"The bubble compresses gas being pushed out ahead of it," says Churchwell. "When that gaseous compression runs into something that is already not too far from gravitational equilibrium, then that added density will cause it to collapse and start forming a star." The confirmation comes not only from observation of these bubbles surrounding single stars, but also their effects: They reveal themselves as green-fuzzy emission regions in false-color infrared images, created when excited molecular hydrogen crashes into the surrounding interstellar medium.



The "green fuzzy" emission region N49 (at center) provides evidence that massive stars can form on the rim of an expanding bubble.
NASA/JPL-Caltech/University of Wisconsin

Churchwell says his team has identified some 300 elongated and extended "green fuzzies" — the smoking guns that indicate a protostar's bipolar outflow. In this sense, they are analogous to the same outflows generated by quasars at the centers of active galaxies. Nevertheless, these green fuzzies are observational evidence that single stellar bubbles can and do trigger follow-on star formation.

Ultimately, however, star formation will be stymied by the limits of the galaxy itself. Unless fed from infalling intergalactic gas or gas accreted from nearby dwarf galaxies, the Milky Way will have to work with the gas on hand. Although the galaxy still has several billion solar masses worth of cold molecular hydrogen left, theorists wonder if the Milky Way will suffer its own energy crisis.

"Estimates indicate the galaxy will use up that molecular gas probably in less than a billion years," says Leo Blitz, an astronomer at the University of California at Berkeley. "Perhaps estimates of how much material is put back into the interstellar medium by the explosion of new stars should also be revised."

Certainly, type II supernovae blow a lot of hydrogen back into the surrounding interstellar medium. And stars that don't go supernova shed most of their unused hydrogen during the endgames of their red-giant phases. McKee estimates that some 30 percent of a star's mass eventually gets returned to the interstellar medium.

Our Sun formed some 4.5 billion years ago, but it can't hang on forever. Just as our own flesh and blood eventually gets recycled, the Sun eventually will cast off its unused hydrogen to be recycled and burn another day. And only now are we fully appreciating just how that all happens.

To learn more about the GLIMPSE and MIPSGAL surveys, visit www.Astronomy.com/toc.

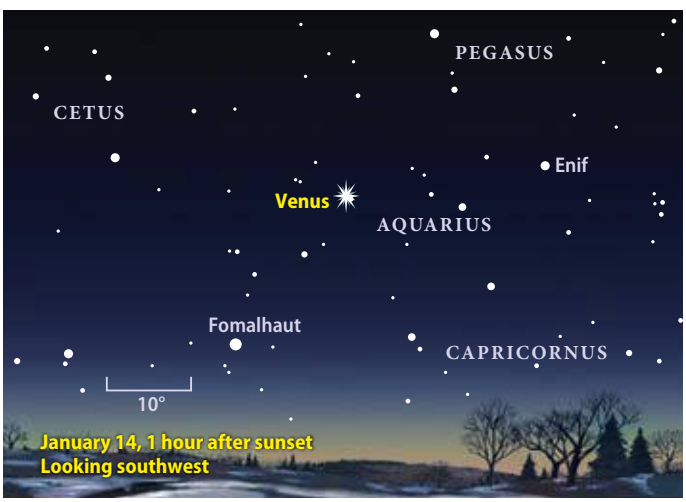
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

January 09

Venus and Mercury peak

A crescent Moon standing next to Venus always looks photogenic, as it did in this scene from June 24, 2006. You'll have a chance to see a similar vista after sunset January 29. David Reese



Venus lies high in the evening sky throughout January. It reaches its peak at greatest elongation January 14. *Astronomy*: Roen Kelly

The International Year of Astronomy opens with Mercury and Jupiter next to each other in the southwest shortly after sunset. Both Mercury and its inner-planet sibling, Venus, reach greatest elongation this month. There's no better time to view these two worlds. Venus stands far above Mercury, and a waxing crescent Moon accompanies them during the year's first week.

You'll have to wait until midnight approaches before another planet rises. Saturn quickly ascends and becomes a spectacular object before dawn. Venus and Saturn rule for long hours each night, while Mercury and Jupiter remain visible only briefly.

Let's begin our journey across the solar system with the first of the inner planets to swing wide of the Sun. **Mercury** reaches greatest elongation January 4, when it stands 19° east of our star. That may not sound like a lot, but it's enough to raise the diminutive planet well above the southwestern horizon as twilight starts to fade.

On New Year's Day, Mercury shines respectably at magnitude –0.7. Thirty minutes after sunset, the planet stands 9° high, enough altitude to make it visible easily if you have a clear and unobstructed horizon. That same evening, **Jupiter** joins Mercury. The giant outer planet lies 2° to Mercury's lower right and appears some 3 times brighter, shining at magnitude –1.9.

A telescope reveals quite a contrast between these two planets. Mercury measures a mere 6" across and shows a phase that's two-thirds lit. Jupiter, now located on the opposite side of the solar system from Earth, spans 33" and appears fully lit.

Each night after the 1st, Jupiter sinks lower and becomes more difficult to see. But while the giant planet's angular distance from the Sun shrinks, Mercury's grows. By the time the inner planet reaches its January 4 maximum elongation, it sets 90 minutes after the Sun.

— *Continued on page 53*

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55 Locating asteroids
55 Mercury in the evening

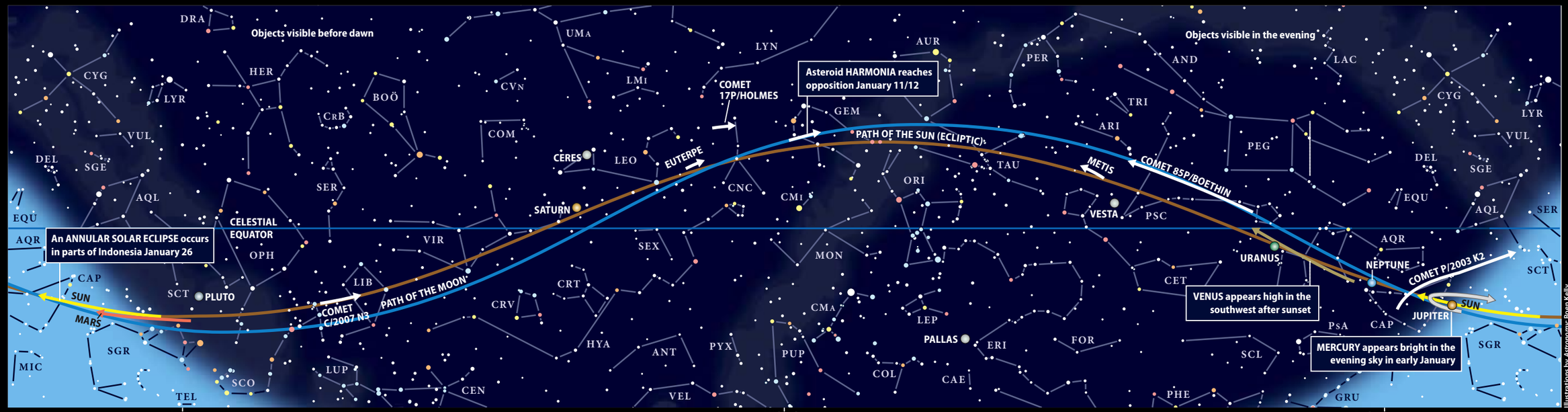
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in January 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



Dawn — Midnight — Early evening

MOON PHASES

27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

31 30 29 28 27 26 25 24

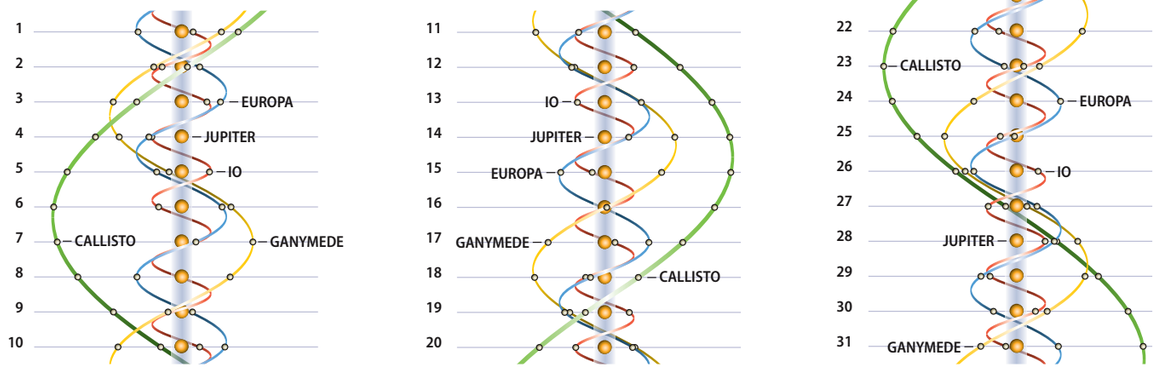
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	January 1	January 15	January 15	January 15	January 1	January 15	January 15	January 15	January 15
Magnitude	–0.7	–4.6	1.3	7.6	–1.9	0.9	5.9	8.0	14.1
Angular size	6.2"	24.4"	3.9"	0.7"	32.6"	18.9"	3.4"	2.2"	0.1"
Illumination	71%	51%	100%	98%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.077	0.685	2.396	1.802	6.039	8.794	20.651	30.899	32.480
Distance (AU) from Sun	0.350	0.721	1.442	2.548	5.114	9.371	20.099	30.034	31.583
Right ascension (2000.0)	20h07.4m	22h54.0m	19h01.2m	11h21.1m	20h04.1m	11h31.9m	23h22.9m	21h40.9m	18h06.8m
Declination (2000.0)	–21°50'	–7°25'	–23°31'	19°11'	–20°48'	5°20'	–4°49'	–14°16'	–17°45'

10" S W E N

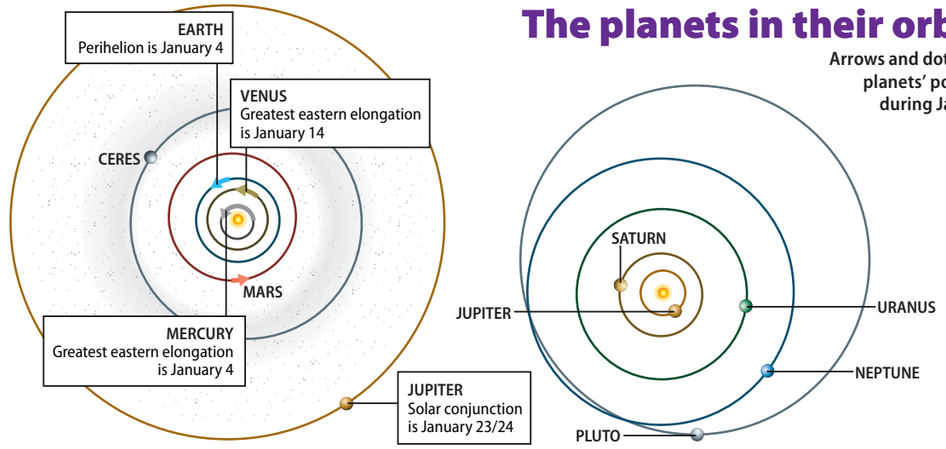
Jupiter's moons

Dots display positions of Galilean satellites at 7 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during January.



StarDome

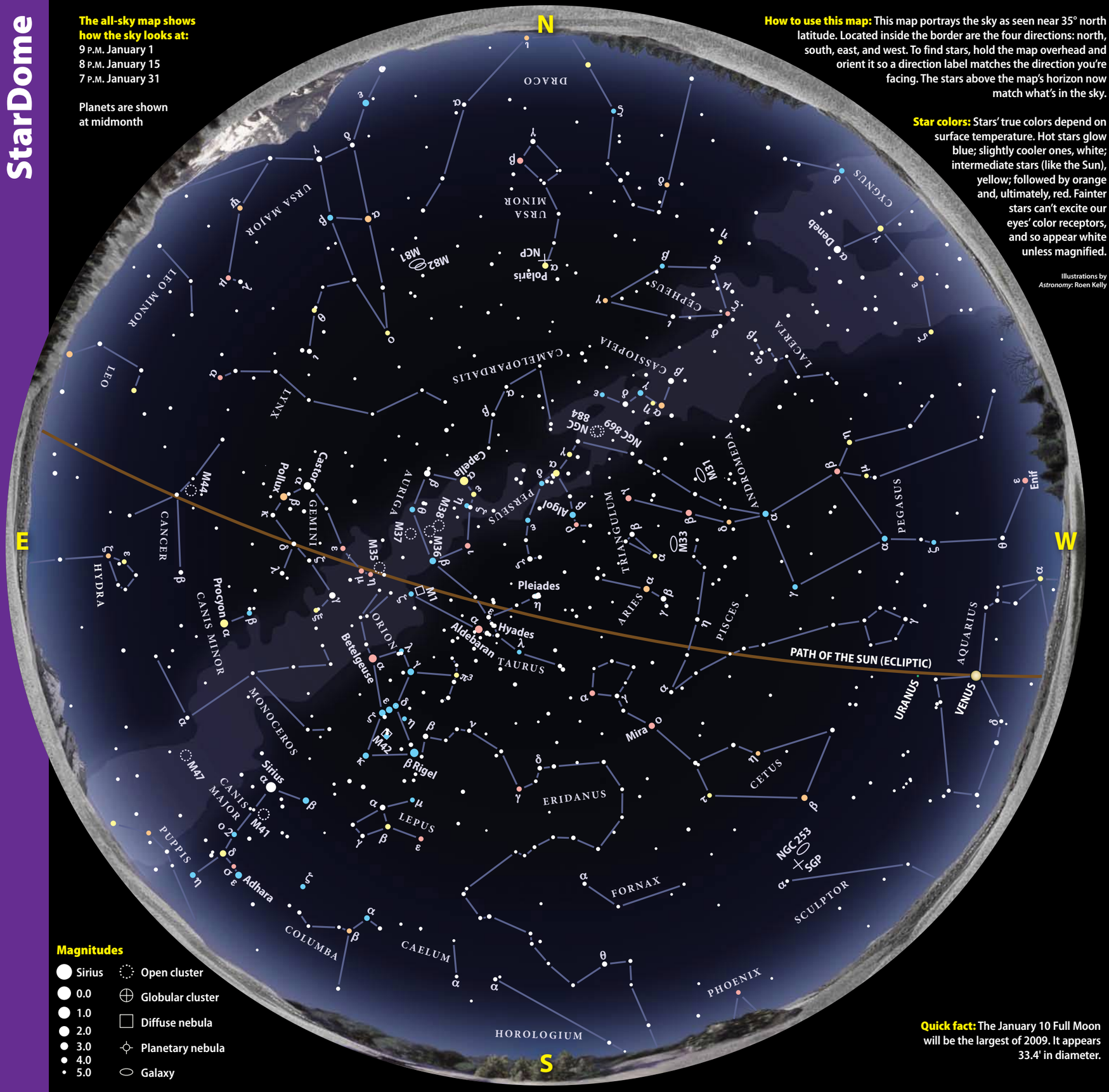
The all-sky map shows how the sky looks at:
9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The January 10 Full Moon will be the largest of 2009. It appears 33.4' in diameter.

January 09

Note: Moon phases in the calendar vary in size due to distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Calendar of events

1 Saturn is stationary, 3 P.M. EST

2 The Moon passes 5° north of Uranus, noon EST

3 Quadrantid meteor shower peaks

4 First Quarter Moon occurs at 6:56 A.M. EST

Mercury is at greatest eastern elongation (19°), 9 A.M. EST

Earth is at perihelion (91.4 million miles from the Sun), 10 A.M. EST

10 The Moon is at perigee (222,138 miles from Earth), 5:50 A.M. EST

Full Moon occurs at 10:27 P.M. EST

11 Asteroid Harmonia is at opposition, midnight EST

14 Venus is at greatest eastern elongation (47°), 4 P.M. EST

Special observing date

14 Venus appears highest in the southwestern sky after sunset.

15 The Moon passes 6° south of Saturn, 7 A.M. EST

17 Last Quarter Moon occurs at 9:46 P.M. EST

18 Asteroid Juno is in conjunction with the Sun, 5 P.M. EST

20 Mercury is in inferior conjunction, 11 A.M. EST

21 The Moon passes 0.02° north of Antares, 8 A.M. EST

22 The Moon is at apogee (252,350 miles from Earth), 7:10 P.M. EST

23 Venus passes 1.4° north of Uranus, 11 A.M. EST

24 Jupiter is in conjunction with the Sun, 1 A.M. EST

26 New Moon occurs at 2:55 A.M. EST; annular solar eclipse

27 The Moon passes 1.8° north of Neptune, 1 P.M. EST

29 The Moon passes 5° north of Uranus, 8 P.M. EST

30 The Moon passes 3° north of Venus, 7 A.M. EST

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— *Continued from page 44*

After sunset January 6, a telescope reveals Mercury's half-lit phase. In the following days, Mercury shows a gradually narrowing crescent. As a result of its diminishing phase, the planet fades despite its increasing size as it pulls closer to Earth. By January 9, it shines at magnitude –0.1. And by the 15th, Mercury will be hard to spot in the bright twilight. It passes between the Sun and Earth January 20.

Venus reaches its greatest elongation 10 days after Mercury. Because Venus orbits 31 million miles farther from the Sun (on average) than Mercury, it swings out significantly wider. On January 14, Venus lies 47° from the Sun in our sky. This greater distance translates into a higher altitude, but that's only part of the reason Venus is so easy to see. The planet also appears brighter than any other point of light in the sky.

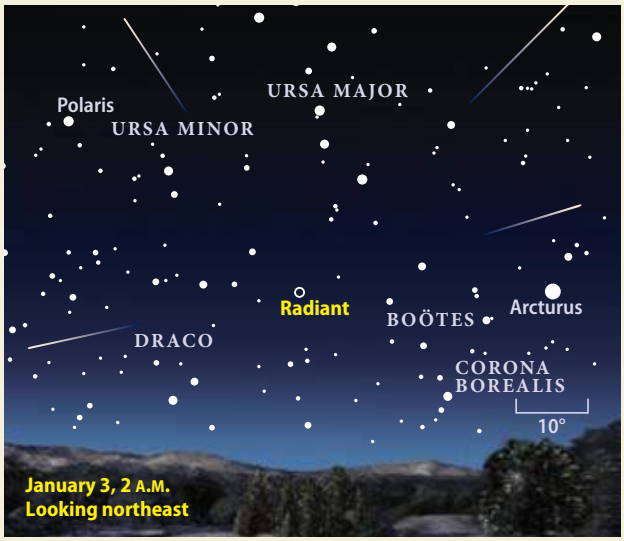
On January 1, Venus shines brilliantly at magnitude –4.4. Its brightness increases to magnitude –4.7 by month's end. The view of Venus through a telescope changes significantly during January as the planet's orbit brings it closer to Earth. On the 1st, it appears 21" across and 58 percent lit. The phase shrinks to half lit by the 16th and to 42 percent by January's close. As the planet's phase diminishes, its diameter increases. It appears 30" wide by the 31st. Anyone with a small telescope can observe these fascinating changes in Venus' appearance.

Venus and a nearby crescent Moon always look photogenic. Watch after the Sun sets January 29, when a 3-day-old Moon lies 6° west of Venus. Photos taken with interesting foreground objects, such as trees or a city skyline, will look particularly impressive.

Those armed with binoculars will be able to spot **Uranus** 4° south of the Moon this same evening. Although

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Quadrantid meteor shower peaks in a Moon-free sky before dawn January 3. Observers who brave the cold may see up to 100 meteors per hour. *Astronomy*: Roen Kelly

Hot times for a cold-weather shower

January's frigid weather hosts one of 2009's best meteor showers. The Quadrantids peak before dawn January 3, when sharp-eyed observers may catch up to 100 meteors per hour. The shower's peak typically lasts only a couple of hours.

This shower's radiant lies in Boötes, in a region once belonging to the now-defunct constellation Quadrans Muralis. The radiant rises before midnight local time, but it doesn't climb above 30° until about 3 A.M. Try to observe between then and dawn. The waxing crescent Moon sets before midnight and won't interfere.

To view the shower, pick an observing site away from the city. Dress warmly and bring along some hot coffee or tea to drink.

Rising Moon

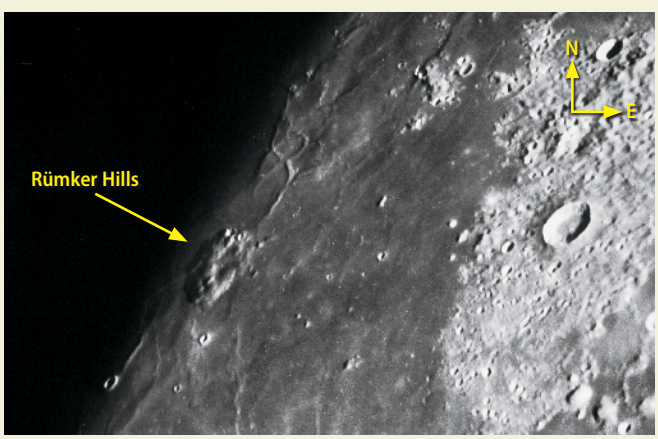
Looking for some lava domes

When the Moon is nearly full, lots of observers pack it in. After all, what's there to see when the Moon shines so bright? But there is plenty to view on the Moon itself. A dark filter will help keep your eyes from being dazzled when observing at low power.

Under non-Full Moon conditions, the myriad craters straddling the terminator — the line that divides dark from light on the lunar surface — catch our attention. On January 8, with Full Moon just 2 days away, the bright rays from young craters like Tycho dominate. But take some time to explore the fairly smooth Oceanus Procellarum, a huge basin on the Moon's western flank.

All here is not flat — take a close look west of the prominent arc of Sinus Iridum (the Bay of Rainbows). A collection of lava domes called Rümker Hills rises from the basin's floor. The hills are named after Karl Rümker, a German astronomer in the mid-19th century. Like all lunar topographic features, these hills show up best at low Sun angles when they cast appreciable shadows.

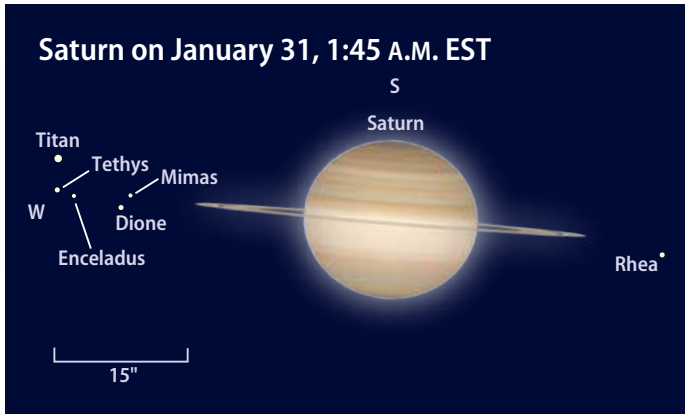
Labeled Mons Rümker in some lunar atlases, these are arguably the most prominent lava domes on the Moon's pock-marked face. Look for a noticeable flat portion on Rümker's eastern flank, which may have resulted from a caldera's collapse. It's definitely not the remains of an old crater because it shows no evidence of numerous smaller impacts. Some nice wrinkle ridges, created when Procellarum slumped, also show up in this neighborhood on the 8th.



The Rümker Hills stand out in western Oceanus Procellarum shortly before Full Moon. These prominent lava domes show up best at low Sun angles (around January 8). *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Saturn (east)	Saturn (southwest)
Venus (southwest)		
Jupiter (southwest)		
Uranus (southwest)		



Five saturnian moons appear near each other — and to Saturn — before dawn January 31. You should be able to spot their relative motions in just a few minutes. *Astronomy*: Roen Kelly

the Moon lies nearby for only a night, Venus remains as a guide to the more distant planet for a couple of weeks. Venus passes 1.4° north of Uranus January 23. (The two appear slightly closer the evening before for those in the Americas.)

Both planets appear in the same binocular field for several days either side of their conjunction. When viewing these planets, take a minute to consider their distances. Venus lies just 57.7 million miles from Earth, while Uranus lies a whopping 1.9 billion miles away.

Uranus glows at magnitude 5.9 throughout January. This makes it a bit fainter than the nearby star 96 Aquarii, which glows at magnitude 5.6. Uranus lies 0.6° east-northeast of 96 Aquarii January 1, a distance that grows to 1.8° by the 31st.

You can find this star 1.6° northeast of 4th-magnitude Phi (ϕ) Aquarii. If you use high magnification on a night with good seeing conditions, your telescope will reveal Uranus' 3.4"-diameter disk. The planet's blue-green disk appears distinctly non-stellar.

Venus also serves as a guide to **Neptune**, although the outermost major planet is a challenge to see. On January 1, 8th-magnitude Neptune lies 6° to Venus' lower right, among the background stars of Capricornus. To locate it, first find 3rd-magnitude Delta (δ) Capricorni. The eastern-most star in the figure of the Sea Goat stands 5° below Venus. Neptune lies 2° to Delta's right, within a 1°-wide circle of stars that glow from 5th to 8th magnitude. Binoculars reveal Neptune, but you'll need a telescope to discern its disk, which appears blue-gray and 2.2" across.

Neptune becomes harder to see as the month progresses and it slips into evening twilight. If you don't look for it in January's first 10 days, you'll be better off waiting until it returns to the morning sky this spring.

The sky remains planetless for an hour or two before midnight, until **Saturn** pokes above the eastern horizon. The ringed planet appears more prominent if you wait until early morning, after 2 A.M. local time. By then, Saturn will climb more than halfway to the zenith.

The planet brightens a bit during January, from magnitude 1.0 to 0.8. It appears as the most conspicuous

Comet search

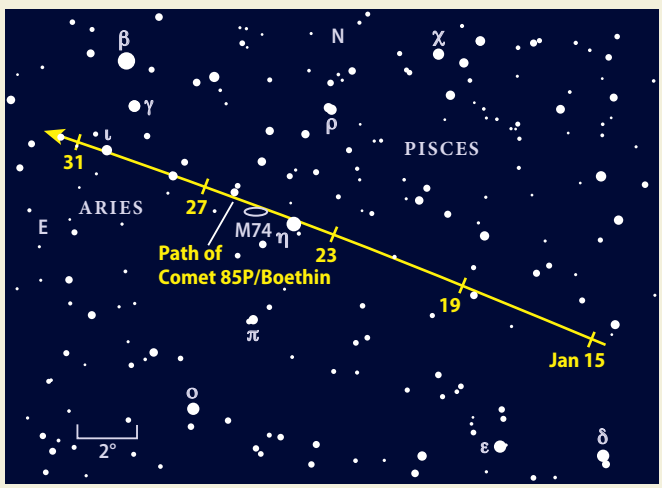
Comets for both morning and evening

January lets us do an end run around the Moon's bright glare. When it washes out the sky near one interplanetary fuzzball, a second one comes into view on the sky's other side. Newcomer C/2007 N3 (Lulin) glides in the Moon-free morning skies during January's first 2 weeks, then the returning Comet 85P/Boethin becomes a prime evening target after midmonth.

Lulin tips the scales of Libra, between ruddy Antares and blue-white Spica. Glowing at 8th magnitude, this primordial snowball hails from the distant Oort Cloud. The comet makes its closest approach to the Sun January 10, but it will continue to brighten as it approaches Earth. It's destined never to return to the inner solar system. You'll need an 8-inch telescope to spy this comet from the suburbs, but a 4-inch will reveal it under a dark sky.

The second half of January belongs to 85P/Boethin. After darkness falls these cold nights, this 8th-magnitude periodic comet wades halfway up the western sky in watery Pisces. It is almost perfectly placed for evening observers.

It passes 0.2° north of the face-on spiral galaxy M74 the night of January 25/26. Neither object has a high surface-brightness, so you'll want a dark sky to see this conjunction well. From the suburbs, only the objects' cores will be visible. You'll see their diffuse outer glows if you observe away from the city.



Comet 85P/Boethin should glow around 8th magnitude in the latter half of January. Look for it near the face-on spiral galaxy M74 after darkness falls January 25. *Astronomy*: Roen Kelly

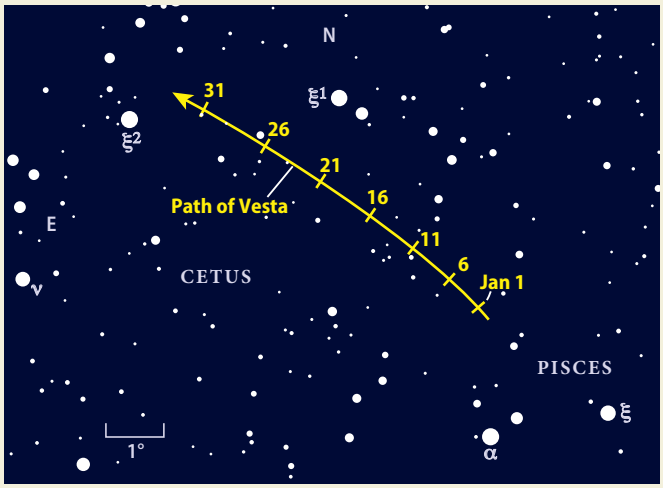
Boethin should show a sharply defined western flank, where the solar wind hits the comet's coma. In contrast, M74 presents a circular glow that yields subtle spiral structure in larger scopes.

Vesta's long, slow goodbye

Starlike asteroids stand up to moonlight and urban sky glow better than fuzzy comets, making them excellent targets for viewing any clear night. Asteroid 4 Vesta appears high in the south in early evening, within easy reach of a 4-inch telescope. Even though it reached opposition last October, Vesta is big enough that it remains reasonably bright for several months.

Use the chart at right to navigate the waters between the tail of Cetus and Pisces. Fortunately, a fair number of 7th-magnitude stars populate this region, acting like buoys to guide you to 8th-magnitude Vesta. Apart from these markers, the rest of the background stars glow considerably fainter than this main-belt asteroid.

You'll have a nice opportunity to see Vesta move from night to night between January 10 and 15. During this period, it enters and then leaves a crooked box outlined by five 7th- and 8th-magnitude stars. Make a simple sketch of these field stars and the asteroid. Then, on subsequent nights, it will be easy to pick out Vesta as the point that moved. Yet another crooked box lies behind Vesta from the 26th to the 28th.



Asteroid Vesta remains an easy target through small telescopes this month, as it makes its way slowly eastward against the background stars of Pisces and Cetus. *Astronomy*: Roen Kelly

object between Regulus, Leo's brightest star, and Virgo's luminary, Spica.

A telescope reveals Saturn's disk, which measures 19" across. But the usually dominant ring system barely shows up because it tilts nearly edge-on from our perspective. This month, the gossamer-thin rings tip just 1° to our line of sight. Large scopes will show them as a barely detectable line that bisects Saturn's disk. The Sun and Earth will pass through the ring plane this summer, when Saturn lies near the Sun in our sky.

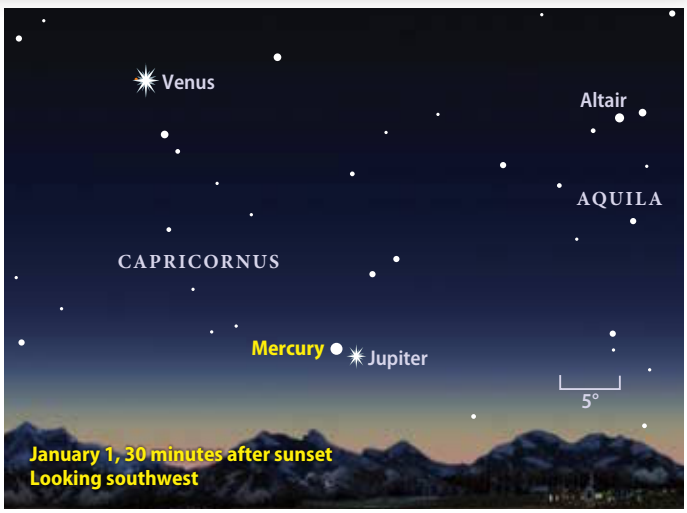
The planet's flattened globe — a result of Saturn's gaseous nature and rapid 11-hour rotation period — appears in its entirety this month. It's a sight experienced viewers of the planet will relish. Typically, the rings block much of one hemisphere. Observers have noticed differences in shading between Saturn's northern and southern hemispheres. Will that difference still be in evidence?

Our edge-on view of the rings means that the orbits of Saturn's major moons also lie nearly in our line of sight. These moons thus appear close to the planet's disk whenever their motions carry them near Saturn. When the rings tilt sharply to our view, as they do in most years, the moons pass well above or below the planet.

Most of the moons and their shadows now transit the planet once each orbit. Although backyard observers will have a hard time seeing the smaller moons as they transit, giant Titan casts a distinct shadow onto Saturn. The first Titan shadow transit will occur February 24.

Look for four of Saturn's major moons to cluster on the western side of the rings the morning of January 31. Enceladus, Tethys, Dione, and Titan lie within 6" of one another and change their relative positions noticeably within minutes. (A smaller moon, Mimas, appears nearby.) Titan also lies close to Saturn's disk January 7, 8, 15, 16, 23, and 24.

January is a good month to spot Iapetus, which swings nearly 10' west of Saturn at midmonth. It then glows at magnitude 10.1, significantly



Mercury shines bright on evenings in early January. It appears highest at greatest elongation, but shows up best when near Jupiter. *Astronomy*: Roen Kelly

brighter than normal because its more reflective hemisphere points in our direction. Iapetus appeared 5 times fainter when it was far east of the planet in early December.

Mars remains out of sight all month. It passed on the farside of the Sun in early December and won't return to view in the predawn twilight until February.

On January 4, **Earth** reaches its closest point to the Sun in its elliptical orbit, a position called perihelion. Winter now reigns in the Northern Hemisphere, while summer's going strong south of the equator.

This simple observation immediately counters the popular misconception that Earth's varying distance from the Sun causes the seasons. The correct explanation involves the tilt of Earth's axis.

Winter in the Northern Hemisphere arises when the North Pole tilts away from the Sun. This pole now lies in perpetual darkness, while the South Pole experiences 24 hours of sunlight each day.

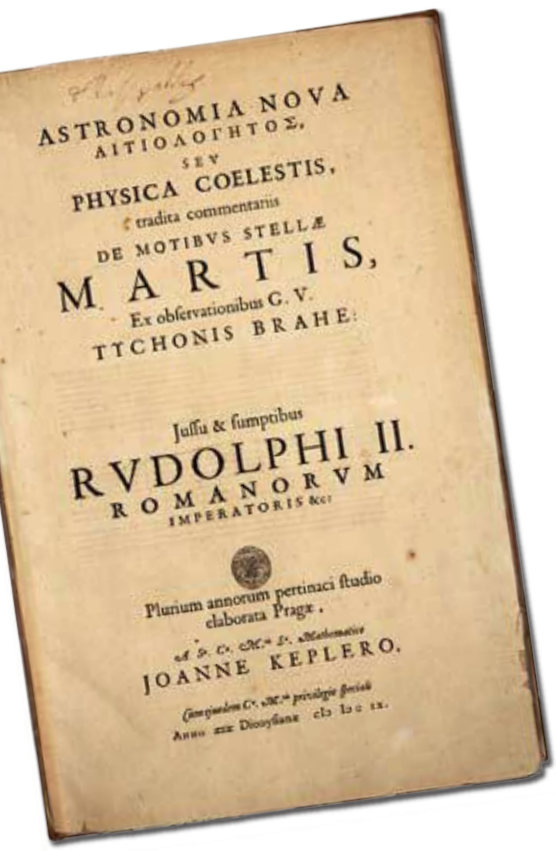
How Johannes Kepler revolutionized astronomy

This 17th-century German astronomer explained planetary orbits, discovered light's inverse-square law, and wrote the first modern book on optics. **by Daniel Hudon**

Johannes Kepler was one of the key figures of the Scientific Revolution. True, he is not as well-known as Galileo or the reclusive genius, Isaac Newton, who built on Kepler's work. But Kepler — Germany's mathematical genius — was a major player in astronomy's history and set the stage for many subsequent important discoveries.

Great discoveries

By describing the process of human vision, Kepler wrote the first modern book of optics, *Astronomiae Pars Optica*. He discovered the inverse square law of light — the foundation for measuring all modern stellar and galactic distances. His thoughts on the shapes of snowflakes resulted in the first book on crystallography, *De nive sexangula*.



The Great Comet of 1577 spread its tail across the sky. This event was an early memory of Kepler's. When he was 5, his mother took him to view the comet when it shone at its brightest. Woodcut by Jiri Daschitzsky, 1577

After Galileo's telescopic discoveries in 1610, Kepler described how the revolutionary new instrument worked. He also introduced improvements, including one that increased the field of view. His design came into wide use by the middle of the 17th century.

We know Kepler mostly for his three planetary laws, which he derived after a Herculean battle with the data of the great Danish naked-eye observer, Tycho Brahe. Kepler linked physics and astronomy by establishing the idea that the planets had to move due to unseen forces. He thus founded celestial mechanics and opened the door for Newton's work on gravitation.

Personal history

Kepler was born December 27, 1571 — 28 years after the death of Copernicus and 7 years after Galileo's birth — in Weil der Stadt, a small, mostly Catholic town on the edge of the Black Forest in southern Germany. Despite being the oldest of four children (three siblings died in infancy), Kepler was always an underdog. His first chore in life was to overcome an unhappy childhood that was plagued by illnesses both real and imaginary.

An early bout with smallpox left Kepler with defective vision — one reason he eventually pursued theoretical rather than observational astronomy. One notably happy event occurred when he was 5. Kepler's mother took him to a hilltop to view the Great Comet of 1577, whose tail arched across the entire sky.

Kepler's first job was as a math teacher in Graz, Austria. It was there that he embarked on his lifelong quest for harmony. In a flight of mathematical mysticism, he tried to link the known planets to Plato's five geometrical solids (the cube, tetrahedron, octahedron, icosahedron, and dodecahedron). By nesting each geometrical solid between the orbits of the planets, he thought he had the basis for the known number of the planets. He was so pleased with this idea, he wrote it up as a sort of "theory of everything" called *Cosmographicum Mysterium* ("The Cosmic Mystery").

The book impressed the most impressive astronomer of the day, Tycho Brahe, and the two men began what quickly became a tempestuous collaboration. Brahe had accumulated 20 years of precise observations and needed someone with Kepler's mathematical prowess to make sense of it. Kepler promised he could solve the orbit of Mars within 8 days. Mars was particularly difficult because the observations varied from Tycho's calculations more than any of the planets. Instead, the task took nearly 8

< *Astronomia Nova*, published in 1609, details Johannes Kepler's work on Mars' orbit. Kepler based his work on the observations Danish astronomer Tycho Brahe had collected over 20 years. Linda Hall Library of Science, Engineering, and Technology

Johannes Kepler produced the three laws of planetary motion, the first detailed observation of a supernova, and an accurate star and planetary position catalog.
Copy of anonymous 1610 portrait

TABVLA III. ORBIVM PLANETARVM DIMENSIONES, ET DISTANTIAS PER QVINQVE REGVLARIA CORPORA GEOMETRICA EXHIBENS.
ILLVSTRISS. PRINCIPI, AC DNO. DNO. FRIDERICO, DVCI WIR-
TENBERGICO, ET TECCIO, COMITI MONTIS BELGARVM, ETC. CONSECRATA.

∧ Kepler used the five geometrical solids of the philosopher Plato to determine the number of planets in our solar system. This illustration is from his *Mysterium Cosmographicum* (1596). Linda Hall Library of Science, Engineering, and Technology

> Kepler built his planetary laws on data acquired by Tycho Brahe. It's fitting that this statue in Prague pays homage to both astronomers. David Koch, NASA

Kepler's Laws of Planetary Motion

1 Planets orbit the Sun in elliptical orbits with the Sun at one focus. (This law destroyed the notion of circular orbits.)

2 A line drawn from a planet to the Sun sweeps out equal areas in equal times. (This law shows why planets [and other objects, like comets] move faster when they lie closer to the Sun than when farther away.)

3 The square of a planet's orbital period, *P*, is proportional to the cube of its semi-major axis (solar distance), *a*. If the period is in Earth years and the semi-major axis is in astronomical units, then $P^2=a^3$. (Astronomers use this law to determine an extrasolar planet's distance from its host star. All they need to know is its period.) — *D. H.*

years and more than 900 pages of calculations before he wrapped it up.

To harmonize observations with calculations, Kepler first determined Earth's motion as a planet. Think of understanding the motion of an airplane circling an airport as seen from another airplane, and you have some sense of the enormity of his task. "I have spent so much pains on it," he wrote a friend, "that I could have died 10 times."

By insisting that his theoretical orbits agreed to within the errors of Brahe's data, Kepler created one of the linchpins of the scientific method. In the process, he swept the astronomical house free of its clutter of circles and epicycles and gave the world two of his three laws of planetary motion: Planets orbit the Sun in ellipses, and a line drawn from the Sun to the planet sweeps out equal areas in equal times. The wheels of the Scientific Revolution were turning, and the ancient notion of uniform circular motion, which even Copernicus held onto, was abandoned for good.

Kepler's nova

In October 1604, a brilliant new star blazed forth in the evening sky. Kepler observed the star and wrote about it in his 1606 work, *De Stella Nova*. As he observed the star, he noted it did not show any parallax.

Parallax is an apparent shift seen as an object is viewed from two locations. A nearby object shows a large parallax, while a distant object shows small parallax. He concluded the object lay within the sphere of the fixed stars.

This conclusion put Kepler at odds with the church. Indeed, how could such a phenomenon occur if the heavens were immutable? Such a "new star" showed the sky does, indeed, change.

Triumph through adversity

Working while suffering religious persecution and financial hardship, Kepler was part mystic and part modern scientist.

Despite constant battles with illness and fever, and tragedies that claimed the lives of his first wife and several of his children, Kepler kept up his quest for harmony. In 1618, his spirit soared when

Daniel Hudon *is a natural science lecturer in the core curriculum at Boston University.*

Kepler searches for Earths

NASA's Kepler mission flies the first spacecraft designed to find Earth-sized planets. It measures the light-drop when a planet crosses in front of its host star. The craft will survey 100,000 stars. Jon Lomberg, NASA

Are there other Earths? This question looms large in the search for extrasolar planets. With the launch of the Kepler Mission, astronomers hope to know the answers soon.

This dedicated space telescope will monitor the brightnesses of 100,000 nearby stars, searching for planetary transits. A transit occurs when a planet passes in front of its host star, causing its light to dim. Johannes Kepler first predicted such an event for Mercury and Venus almost 400 years ago.

But the transit method has challenges. Viewed from Earth, planets have only a small chance of crossing in front of their host stars. During a transit, earthlike planets will cause the host stars' brightnesses to dip by only 1/10,000. Of course, such a dip could be caused by a star spot or the star's own brightness variation. So astronomers must monitor stars precisely for several years to catch recurring transits.

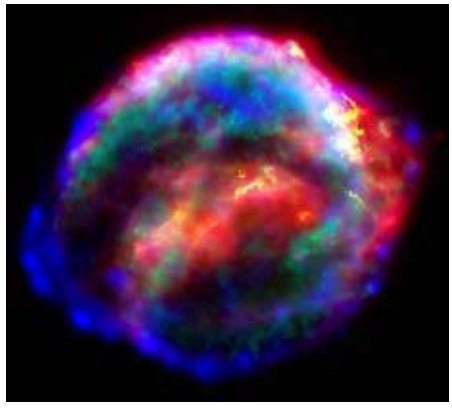
The Kepler Mission's main instrument is a 37.4-inch (0.95 meter) photometer that has a particularly large field of view — 105 square degrees. That area is equivalent to two "scoops" of the Big Dipper. If other Earths are common, then Kepler will detect hundreds.

Johannes Kepler's last work, *Somnium* ("The Dream") was a pioneering science fiction novel about a man's voyage to the Moon. Finding Earths will be like a dream come true for many. — *D. H.*

Kepler plotted the position of "his" nova (marked by an "N" near bottom-center) accurately against the stars of the constellation Ophiuchus. Linda Hall Library of Science, Engineering, and Technology

JOANNIS KEPPLERI
STELLA NOVA
IN PEDE SERPENTARII, ET
TRIGONO IGNEO.
PRAGAE

Kepler's *De Stella Nova*, published in 1606, described a "new star" (what astronomers now call a supernova) he observed in October 1604. Linda Hall Library of Science, Engineering, and Technology



The supernova remnant from the "new star" Kepler observed in 1604 continues to expand today. Three of NASA's space-based observatories — Hubble, Spitzer, and Chandra — collaborated to make this image. NASA/ESA/R. Sankrit and W. Blair (Johns Hopkins University)

he discovered the third of his planetary laws while revising his book, *The Harmony of the World*. He considered this law — that the cube of a planet's distance is proportional to the square of its orbital period — one of his greatest achievements. It now forms the basis of the solar system's structure.

In 1627, he completed *The Rudolphine Tables*, a culmination of his life's work, by combining Brahe's data with his planetary laws. The tables remained astronomy's most accurate resource for decades. Astronomers used them to predict the first observed transits of Mercury and Venus in 1631 and 1639, respectively. Observations of these events helped solidify acceptance of the heliocentric model and Kepler's laws.

Kepler rarely called attention to his accomplishments — he was the first scientist to advocate freely sharing data — and wanted nothing more than to devote his life to philosophical speculation. But time and again he was forced to take to the roads to flee religious turmoil brought on by the Counter Reformation or to seek secure employment. He died of a fever November 15, 1630, while searching for another job. Though his grave was lost in the Thirty Years War, the epitaph he wrote for himself remains:

I measured the skies, now the shadows I measure,
Skybound was the mind, earthbound the body rests.

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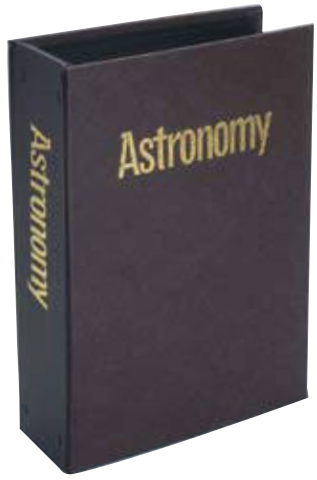

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Do transits reveal Earth to aliens?

Q: Could aliens detect Earth when it crosses the Sun during a transit?
— James S. Morrison, Reno, Nevada

A: Yes, under certain conditions. The civilization's star must be in our galactic neighborhood — say, within 200 light-years — and lie in a part of the sky nearly aligned with the ecliptic, which marks the plane of our solar system. This way, Earth's orbit around the Sun appears edge-on to their view.

Alien astronomers would measure a small periodic drop in the Sun's brightness every time Earth's orbit carries it across the Sun's disk from their perspective. Such an event is called a transit, and it's one method by which terrestrial astronomers have discovered planets orbiting other stars. Extraterrestrials could detect Earth with technology no more advanced than our own.

Once they note our presence and determine Earth's orbital period, the aliens easily could calculate that Earth lies within the Sun's habitable zone, where temperatures allow liquid water to exist on the planet's surface.

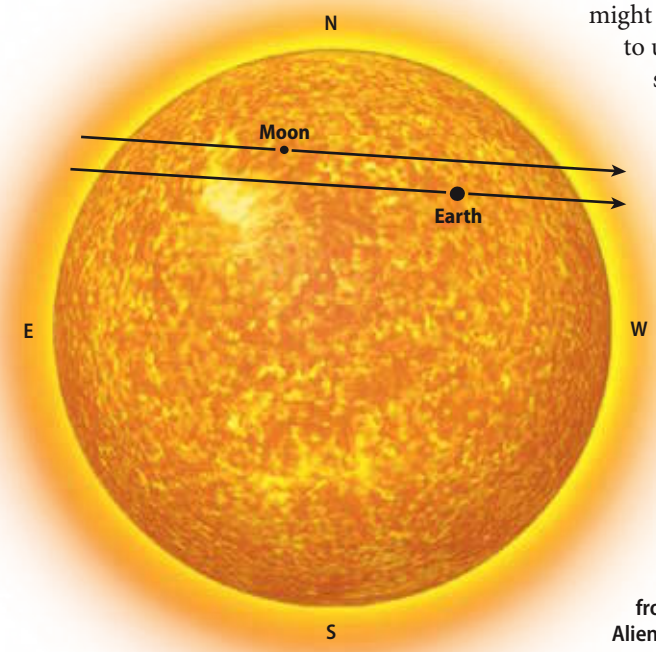
Technology slightly more advanced than what earthly astronomers now use, such as a 16-meter optical space telescope, could provide information on the presence of oceans and the atmosphere's chemical composition.

Sensing oxygen, ozone, methane, and other biotracers would show that Earth hosts life. With more advanced technology, aliens could use radio telescopes to pick up our radio and television signals.

In 2002, SETI Institute astronomer Seth Shostak and I published a paper on this. We proposed that a civilization might even beam a contact signal to us when we appear in transit to them.

Searching for such a signal would mean looking at ecliptic stars opposite the Sun at any given time. We hope to do this using the new Allen Telescope Array, a radio telescope in California.

— Ray Villard, Space Telescope Science Institute, Baltimore



Earth and the Moon track across the Sun's disk as seen from Mars November 10, 2084. Alien observers in a star system aligned to the plane of Earth's orbit would see a similar event. *Astronomy:* Tonya Limberg

BIG AND SMALL

Q: How big are black holes? Are they spherical?
— Gaia Burrage, Slidell, Louisiana

A: A black hole's size is directly proportional to its mass. If it isn't rotating, it will be precisely spherical.

When scientists talk about a black hole's size, they're referring to the diameter of its event horizon — the surface beyond which nothing can escape. The supermassive black hole (with a mass between 3 and 4 million Suns) at the Milky Way's center measures 11 to 15 million miles (18 to 24 million kilometers) across. So-called intermediate-mass black holes weighing in at 1,000 to 10,000 Suns have diameters comparable to planets — up to 37,000 miles (60,000 km).

The smallest are stellar-mass black holes, with up to 20 or so solar masses. The Sun is not big enough to collapse into a black hole. But if it did, its diameter would measure 3.7 miles (6 km) across. If we could turn Earth into a black hole, its event horizon would span a mere 0.7 inch (1.8 centimeters).

These numbers assume a black hole with no spin. Rotation squashes a black hole along its spin axis and flattens it. If a black hole spins at its maximum possible rate, the object's circumference through its poles is ⅜ the circumference around its equator.

Black holes never flatten so much that they become disk shaped. But gas falling into a black hole often forms an accretion disk around a hole before falling in.

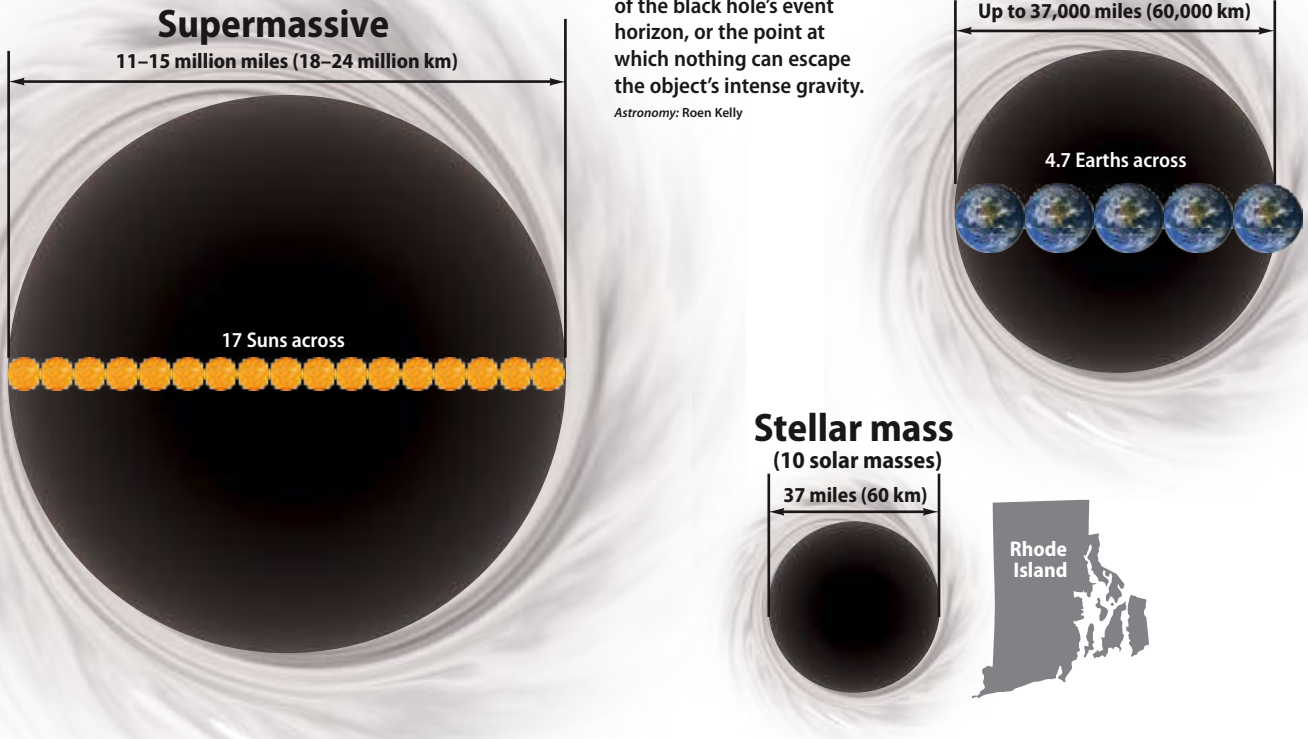
— Scott A. Hughes, Massachusetts Institute of Technology, Cambridge

SCENIC VISTA

Q: Is there a point between the Milky Way and Andromeda where one could see both galaxies with the naked eye? How big would they be? — Eitan Kantor, West Hempstead, New York

A: That spot lies about 1.25 million light-years from Earth. It is the halfway mark between the Andromeda Galaxy (M31) and the Milky Way. If you

How big are black holes?



Black holes increase in size with greater mass. The diameter is measured to the edge of the black hole's event horizon, or the point at which nothing can escape the object's intense gravity.

Astronomy: Roen Kelly

KEY WORDS

Ecliptic
The plane of Earth's orbit around the Sun.

Event horizon
The "surface" of a black hole, beyond which nothing can escape.

Galactic midplane
An imaginary plane between a galaxy's northern and southern halves.

Off-axis filter
A filter positioned to one side of a telescope's optical path.

SETI
An acronym for the Search for Extraterrestrial Intelligence.

could go there, you would see both galaxies lying opposite each other. **To human eyes, each galaxy would span roughly 6° of the sky — twice M31's apparent size as seen from Earth, and 12 times the Full Moon's width.** — **Abraham Loeb,** Harvard University, Cambridge, Massachusetts

Do galaxies have magnetic fields? Get the answer at www.Astronomy.com/toc.

SUNSPOTTING

Q: Is it possible to do solar observing and imaging with a large-aperture Newtonian or Dobsonian telescope? — **Jim Cooksey,** Hudson, Wisconsin

A: You can observe the Sun through any size or type of telescope. The key is to fit the front end of the scope with an approved solar filter to block the Sun's harmful rays.

Some observers think the image through a full-aperture solar filter, although safe, appears a bit bright. So, for a large-aperture (10 inches or greater) Newtonian scope, I suggest you purchase an off-axis filter. It's an end cap for the telescope with a small, off-center circular opening containing a solar filter.

This arrangement allows much less light to enter the telescope, thus reducing the brightness of the image you see. Better yet, the small opening can be positioned between the vanes supporting the scope's secondary mirror so that these obstructions don't compromise the view.

A word of warning: Never use an eyepiece solar filter with any size telescope. This filter type can crack as the scope focuses the Sun's energy onto it. It's much safer to keep the energy completely out of the scope's tube. — **Michael E. Bakich,** Senior Editor

GALACTIC RIDE

Q: In what direction and at what speed is the solar system moving through the Milky Way? — **Sayed Alawi,** Anaheim, California

A: The Sun and most nearby stars appear to orbit the Milky Way's center. **Compared to the average motion, the Sun appears to move a little faster — 16,000 mph (25,200 km/h) — than the general rotation. It's moving toward the galactic center at 22,000 mph (36,000 km/h) and slightly upward at 11,000 mph (18,000 km/h).**

Research suggests the Sun crosses the galactic midplane about every 30 million years. We're now about 49 light-years above the galaxy's midplane. Eventually, the Sun may rise as high as 1,140 light-years above the plane — above most of the Milky Way's gas and dust. This position would provide a much clearer view of our galaxy than we now have.

— **Robert Benjamin,** University of Wisconsin-Whitewater

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Explore the sky's spooky reflection nebulae

You'll need a big scope and a dark sky to explore the van den Bergh catalog's challenging objects.

text and images by Thomas V. Davis

Reflection nebulae are the unsung sapphires of the sky. These vast glowing regions represent clouds of dust and cold hydrogen scattered throughout the Milky Way. Reflection nebulae mainly glow with subtle blue light because of scattering — the principle that gives us our blue daytime sky.

Unlike the better-known red emission nebulae, stars associated with reflection nebulae are not near enough or hot enough to cause the nebula's gas to ionize. Ionization is what gives hydrogen that characteristic red color. The star in a reflection nebula merely illuminates surrounding dust and gas.

Many catalogs containing bright emission nebulae and fascinating planetary nebulae exist. Conversely, there's only one major catalog of reflection nebulae.

Reflections of starlight

Canadian astronomer Sidney van den Bergh published a list of reflection nebulae in *The Astronomical Journal* in 1966. His intent was to catalog "all BD and CD stars north of declination –33° which are surrounded by reflection nebulosity …"

BD stands for *Bonner Durchmusterung*, a comprehensive astrometric catalog of stars spanning the entire northern sky, processed by the Bonn (Germany) Observatory from 1859 to 1903. The BD catalog includes 325,000 stars as faint as visual magnitude 10.

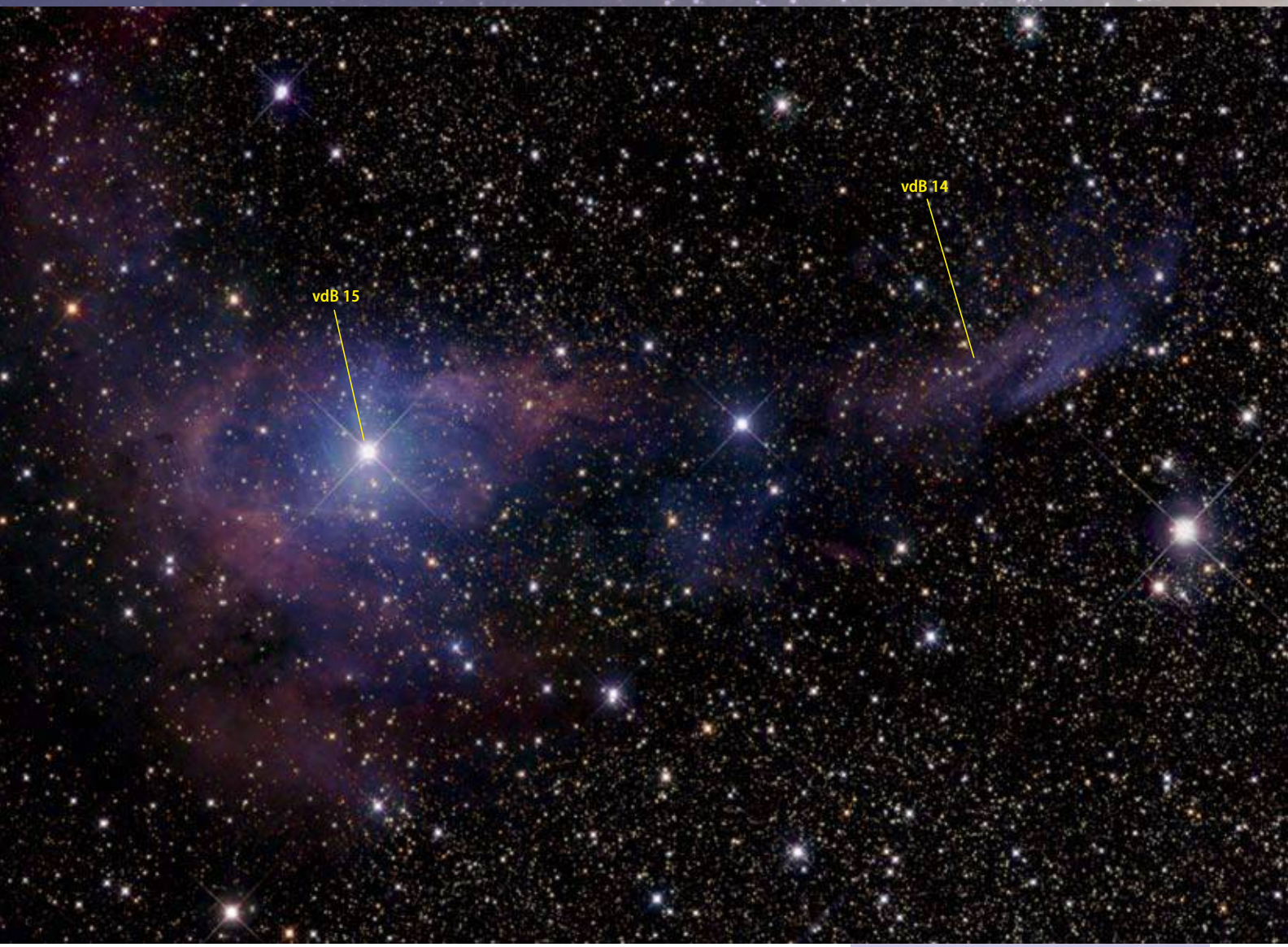
Conversely, CD stands for *Cordoba Durchmusterung*, a similar astrometric star catalog compiled in Cordoba, Argentina. It covers the southern sky.

Van den Bergh used those star catalogs and photographic plates from the

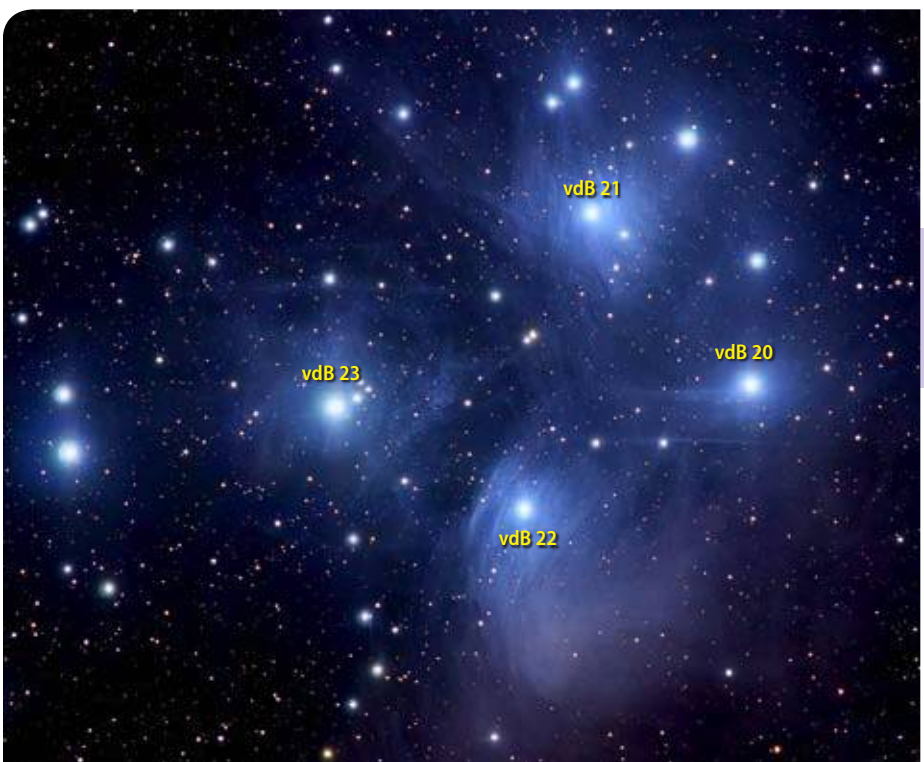
The Iris Nebula (NGC 7023) also carries the designation van den Bergh (vdB) 139. This beautiful, flower-like cloud of gas and dust sits in Cepheus. The author combined a total of 6 hours and 6 minutes of exposures to record the faint detail in this image.

vdB 132 in Cygnus (the fuzzy blue area in the center) required a total of 8 hours and 50 minutes of exposures, and it still appears faint against the glowing red hydrogen clouds of the Gamma Cygni region.

Thomas V. Davis *images faint objects under the dark skies of Inkom, Idaho.*

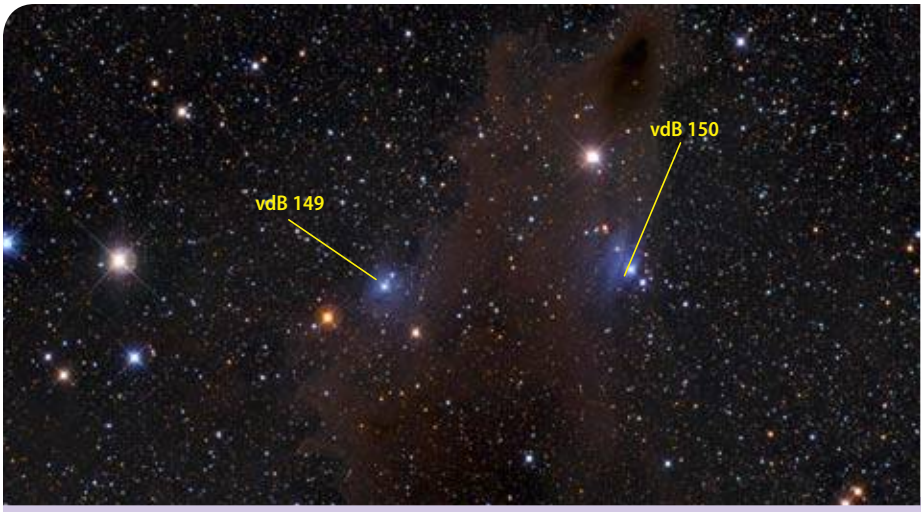


vdB 14 and vdB 15 in Camelopardalis are so faint they essentially lie outside the realm of visual observers. This LRGB image combines 330 minutes of unfiltered (L) exposures, 70 minutes through red (R) and blue (B) filters, and 60 minutes through a green (G) filter.

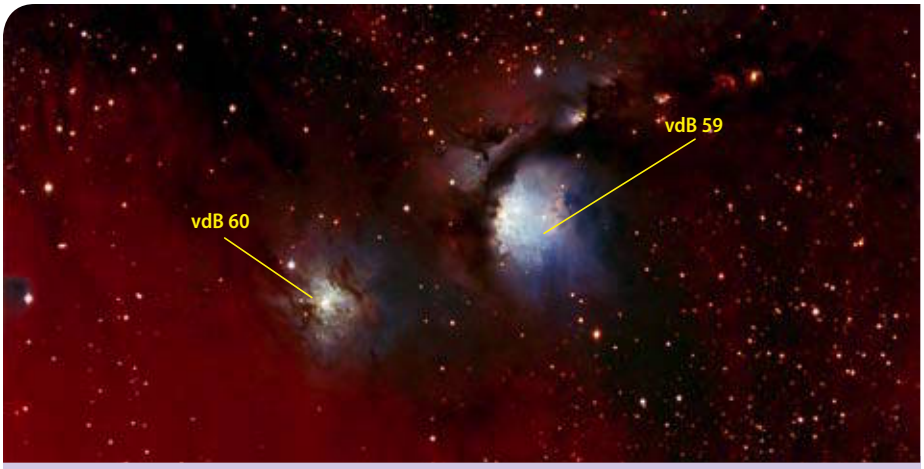


The Pleiades (M45) contains four van den Bergh objects. The brightest and most famous — vdB 22 — surrounds the star Merope (23 Tauri). Reflection nebulae vdB 20, vdB 21, and vdB 23 also lie within this complex.

The Flaming Star Nebula (IC 405) in Auriga also carries the designation vdB 34. Most of the gas here glows red by reemitting radiation from the hot star AE Aurigae. Sidney van den Bergh found a blue component to this object, and made it number 34 in his catalog.



vdB 149 and vdB 150 are small faint reflection nebulae that lie within a massive dust cloud in Cepheus. The author required more than 10 hours of total exposure time to record this region. The dark nebula just above vdB 150 is Lynds Dark Nebula 1235.



M78 in Orion is the sky's brightest reflection nebula, but there's a lot more going on in this region than reflection. Emission nebulosity (in red) and dark nebulae also abound. Two of M78's blue components carry the designations vdB 59 and vdB 60.

Palomar Sky Survey taken with the 48-inch Samuel Oschin Schmidt camera to identify reflection nebulae. In his original paper, van den Bergh said, "To avoid inclusion of doubtful objects and plate defects only those nebulae which were visible on both the blue and red prints … were included in the final catalog."

The catalog lists 158 reflection nebulae. The nearer nebulae lay predominantly in Gould's Belt, a collection of stars that forms a roughly elliptical ring 3,000 light-years across and tilts 20° to the galactic plane. The more distant nebulae lie mainly along the galactic equator.

Van den Bergh added comments regarding the size of each nebula, the illuminating star, that star's position relative to the nebula (embedded or outside), the star's spectral type, and the nebula's brightness and color.

Many reflection nebulae are difficult for visual observers to find because those objects are so dim. However, with the introduction of charge-coupled device (CCD) technology, amateur astronomers are finding it easier to locate — and especially image — them. Indeed, astroimages now offer up the once-hidden secrets of these dusty nebulae.

Astronomers have determined this dust is complex and non-spherical. It's predominantly silicon dioxide, amorphous carbon, iron silicates, magnesium, and water ice. These dust particles are minute (10^{-5} centimeters) and often align with the Milky Way's magnetic field. This slightly polarizes the reflected light.

The dust within a reflection nebula scatters short-wavelength (blue) light more efficiently than longer wavelength (red) light. That's what gives these nebulae their classic, but not all inclusive, blue appearance on digital and film images.

Delve into the catalog

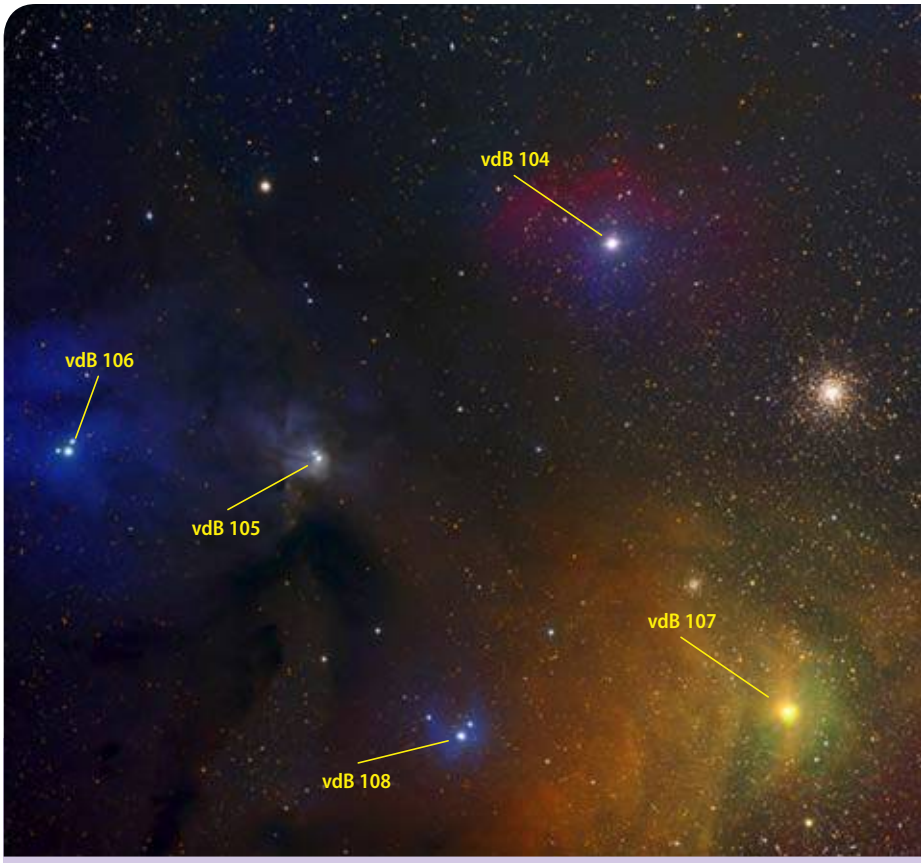
Objects in the van den Bergh (vdB) catalog vary from small, indistinguishable wisps to large, commanding patches of nebulosity. Amateur astroimagers have not photographed many of these objects to any level of detail, but amateurs seasonally target a few of the brighter ones as the celestial sphere marches overhead.

Astrophotographers don't commonly image vdB 27 in Taurus because it's so faint. The region shows a wealth of reflection and dark nebulosity. The author combined exposures totaling 640 minutes of exposure time to produce this image.

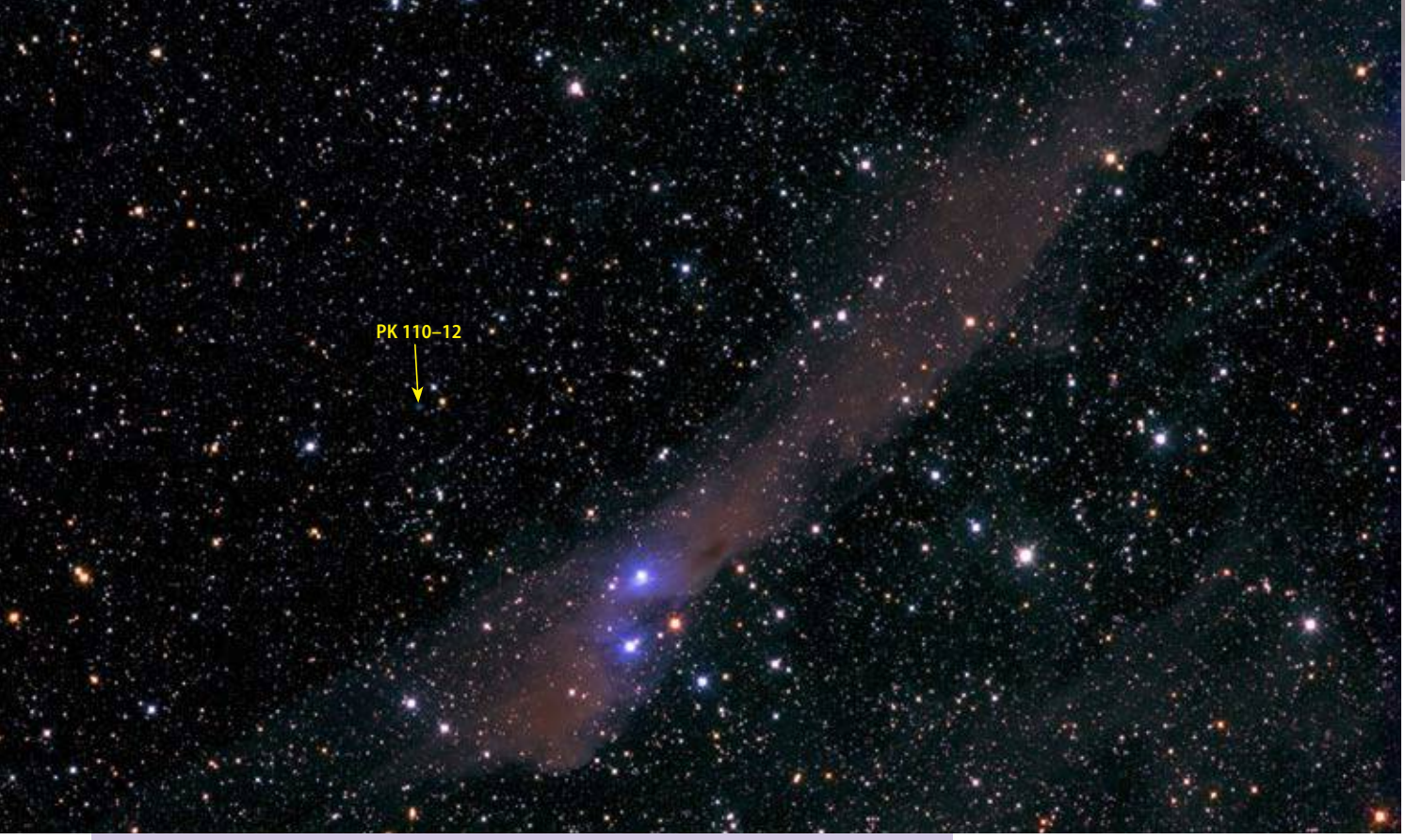
Some of the more popular, yet unrecognized, vdB objects include the nebulosity surrounding the stars of the Pleiades (M45). Amateur astronomers know vdB 22 as the famous Merope Nebula (NGC 1435), which surrounds 22 Tauri. Conversely, vdB 20, 21, and 23 represent nebulae associated with the Pleiades' "sister" stars Electra (17 Tauri), Maia (20 Tau), and Alcyone (Zeta [ζ] Tau), respectively.

Another commonly imaged vdB object is number 139, also known as the Iris Nebula (NGC 7023). Extensive clouds of dust surround this reflection nebula. These clouds often go undetected in images with narrow fields of view. All of these dust clouds are parts of the same extensive system.

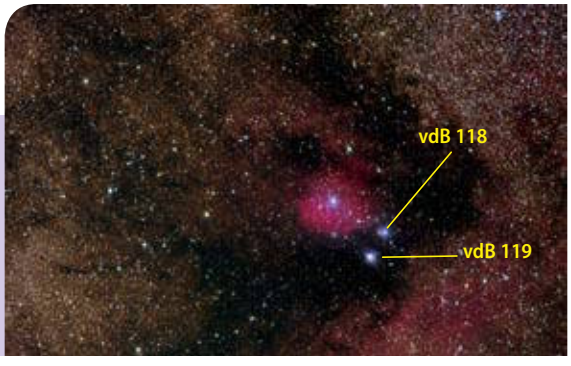
Other frequently visited, yet unrecognized, vdB objects include vdB 59 and 60 (also known as M78 — the sky's brightest reflection nebula); vdB 34 (the Flaming Star Nebula [IC 405]); vdB 17 (in NGC 1333); vdB 106 (in the Rho Ophiuchi



The Rho Ophiuchi region stretches into neighboring Scorpius. A treasure-trove of different types of objects reside here. Sidney van den Bergh cataloged five reflection nebulae — vdB 104, vdB 105, vdB 106, vdB 107, and vdB 108 — in this region.



vdB 158 in Andromeda is difficult to image because of its low surface-brightness. The author collected a total of 9½ hours of exposures for this shot. Note the small blue planetary nebula PK 110–12 to the upper left of the main blue reflection nebula.



vdB 118 and vdB 119 are tiny reflection nebulae in this wonderfully rich Milky Way region in Sagittarius. It's hard to ignore the beautiful red emission nebulosity here, but, remember, we're focusing on van den Bergh's objects.

vdB 152 (upper left) glows with the characteristic blue color of reflection nebulae at the end of a dusty curtain of dark gas and dust. It lies about 1,400 light-years away, along the northern Milky Way in Cepheus. The entire complex is a huge molecular cloud that will form stars.

Nebula); and vdB 107 (the Antares Nebula). These objects are perennial favorites of amateur astronomers the world over.

Some vdB objects are commonly mislabeled. One such is vdB 142 in Cepheus. This small nebula often erroneously carries the name the Elephant Trunk Nebula. Actually, vdB 142 is the small reflection nebulosity adjacent to the star SAO 33573. The correct designation of the Elephant Trunk Nebula is IC 1396A.

Finally, many van den Bergh objects have no readily available detailed color images. These overlooked gems pass season after season without stirring much interest, going essentially unnoticed while more alluring targets gather all the attention. Today, however, it's easier than ever to capture them. Combine a moderate aperture, fast focal-ratio telescope with a CCD camera, image for long periods (or combine a series of exposures), and you'll reveal the beauty of these once-hidden deep-sky wonders.

Whether you discover the van den Bergh objects by eyepiece or by camera, your reward will be a new depth of satisfaction as you hunt down these overlooked sapphires of the night sky.

Download a PDF file of the entire van den Bergh catalog at www.Astronomy.com/toc.

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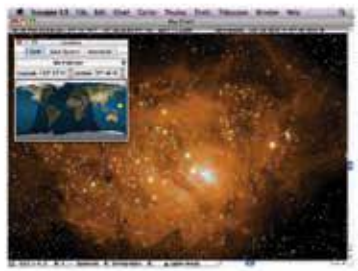

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The crisp, clear skies of winter beckon beginning observers.

by Michael E. Bakich

The winter sky offers the brightest stars of any season. This makes finding the constellations that contain them easy. At this time of year, the Milky Way arches from north to south. Along that path, deep-sky treasures visible through binoculars abound. All you need is this story and a way to stay warm.

Toward the south, look for the magnificent constellation **Orion** the Hunter. Orion looks like a giant butterfly, with the three stars of his belt marking the butterfly's body and wings to either side.

Orion's brightest star is **Rigel** (Beta [β] Orionis). It marks his left foot (the one to the bottom-right, as we see it in the sky).

Notice the description of Rigel in parentheses. You'll see a Greek letter, the letter in Greek, and the possessive form of the constellation name. Only a few hundred stars have proper names, but about a thousand have Greek letters associated with them. This practice began with German mapmaker Johann Bayer (1572–1625) in his star atlas *Uranometria*, published in 1603. Astronomers have used his designations ever since.

To Rigel's upper-left, past Orion's belt, lies **Betelgeuse** (Alpha [α] Orionis). Although modern descriptions list Betelgeuse as one of Orion's shoulders, the original Arabic name more closely means "the armpit of the mighty one."

As you view Rigel and Betelgeuse in the sky, you'll notice they have quite different colors: Rigel is bright blue, and Betelgeuse shines with a coppery tone. Stars shine with different colors because their surfaces radiate at different temperatures. Blue stars typically have surface temperatures above 50,000° F (22,750° C). The surface of a red star like Betelgeuse heats the thermometer to only 3000° F (1650° C).

In the region of Orion's sword, which hangs below his belt, sharp-eyed observers will see the area as slightly fuzzy. This is the Orion Nebula (**M42**) — a huge star-forming region. Binoculars improve the view, but a small telescope with an eyepiece that gives a magnification of about 100x works best.

Because Orion is so easy to find, you can use it to locate many other stars and constellations. For example, if you draw a line down to the southeast from Orion's Belt, you'll arrive at **Sirius** (Alpha Canis Majoris), the night sky's brightest star. Because of its position in **Canis Major** the Big Dog, the ancient Greeks referred to Sirius as the Dog Star.

Point your binoculars at Sirius and move the star so it sits at the top of the field of view. Near the center, you'll see the open star cluster **M41.** Open clusters are loose collections of dozens to hundreds of stars that all formed out of the same nebula. Few open clusters are old. That's because a cluster's stars disperse over millions of years due to gravitational interactions within the cluster.

Canis Major isn't Orion's only dog — there's also **Canis Minor** the Little Dog. To find it, make an equilateral triangle

Auriga the Charioteer contains the sky's sixth-brightest star, Capella. This constellation lies directly north of Orion the Hunter. Auriga's position along the winter Milky Way guarantees that you'll find many bright open star clusters in this area. All images: Bill and Sally Fletcher

Go to the map

Use the star map in the center of the magazine with this story. **Bold words** are objects you'll find on the map.

Michael E. Bakich *is a senior editor of* Astronomy. *Long Midwest winter nights provide lots of chances for him to observe.*

using Betelgeuse, Sirius, and Canis Minor's brightest star, **Procyon.** These three stars form a bright asterism (a recognizable star pattern that's not a constellation) called the Winter Triangle. Once you find Procyon, draw a line up to Beta Canis Minoris and you've outlined the little dog — just two stars!

Now draw a line from Orion's Belt in the opposite direction. You'll soon come to a V-shaped group of stars called the **Hyades**, which marks the head of **Taurus** the Bull. Taurus' fierce eye is the ruddy star **Aldebaran** (Alpha Tauri).

Continue the line upward, and you'll hit the **Pleiades** (M45). This naked-eye star cluster (sometimes called the Seven Sisters) appears best through 10x to 15x binoculars. Telescopes tend to magnify the cluster too much, reducing the number of stars you'll see at once.

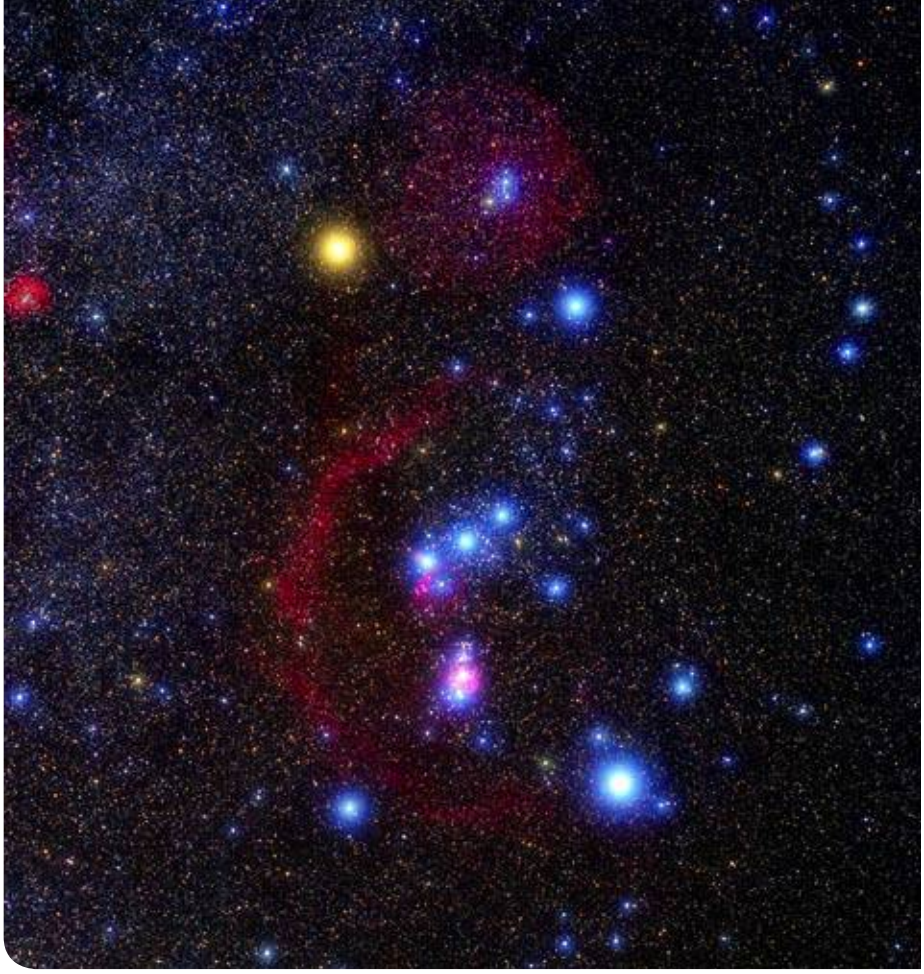
If you extend a line straight up through Orion's body and head, you'll find **Auriga** the Charioteer. The brightest star in this constellation is yellow **Capella** (Alpha Aurigae). Capella is a word that means "mother goat," and early observers called the triangle of faint stars just to the southwest of Capella the "kids."

Auriga lies in the heart of the Milky Way, so deep-sky objects abound here. Three open clusters — **M36**, **M37**, and **M38** — look nice through binoculars and spectacular through a telescope.

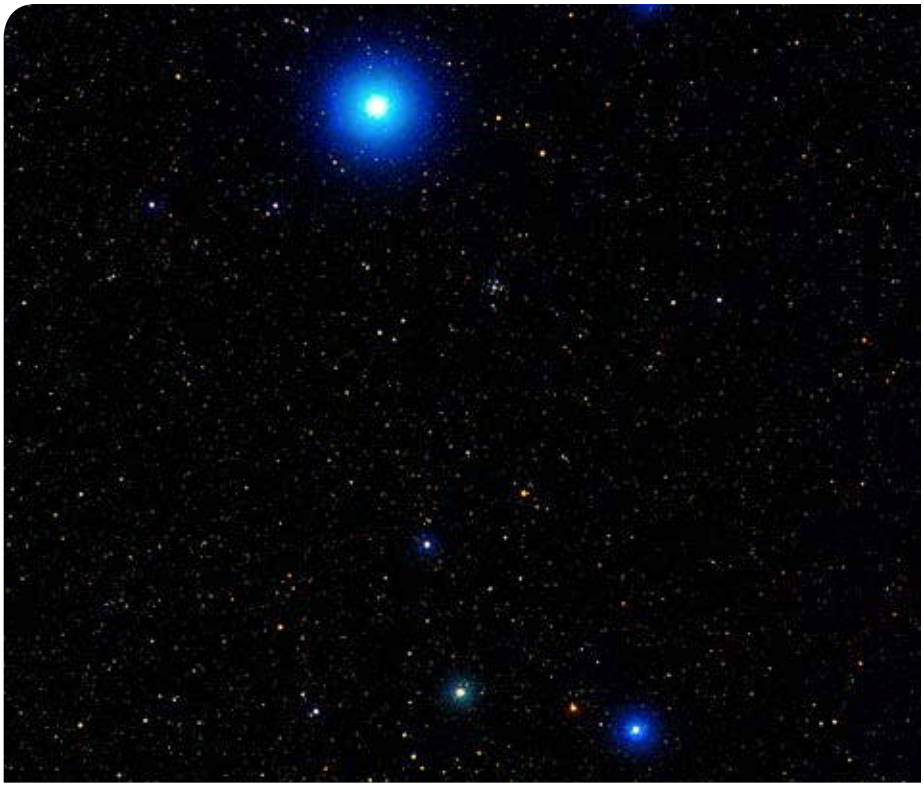
Return to Orion one last time. Draw a line from Rigel to Betelgeuse. Continue the line about 1½ times that distance to find **Gemini** the Twins. The two stars marking the Twins' heads are **Castor** (Alpha Geminorum) and **Pollux** (Beta Geminorum). In the sky, an easy way to tell which is which is to remember a bright star first-letter match: Castor lies closer to Capella, and Pollux is on the same side as Procyon.

M35 is a bright open star cluster in Gemini. It lies a bit more than 2° (4 Full Moon-widths) northwest of Eta (η) Geminorum. Place Eta in the center of your binocular field, and M35 will be visible to the star's upper right.

Learning the major constellations and bright stars in the winter sky is easy, even from a brightly lit backyard. And if you chill quickly, just 5 or 10 minutes a night will do it. In a short time, you'll be sharing these objects with others. And you won't even need a star map.



Orion the Hunter is the sky's most famous constellation and winter's brightest. Start your winter sky tour here. In this image, Barnard's Loop, a vast, red gas cloud visible in photographs, lies in the same direction as Orion. The Rosette Nebula (NGC 2237–9) in Monoceros sits at the left edge.



Sirius is sometimes called the Dog Star because it's the brightest star in Canis Major the Big Dog. Blazing at magnitude –1.47, Sirius outshines every other nighttime star. If the winter air above your observing location is unsteady, Sirius will twinkle like a twirling diamond.

Equipment review

Orion's StarBlast 6 makes a great first scope

This grab-and-go telescope offers 6 inches of light-gathering in a compact design.

by Glenn Chaple

In 2003, California-based Orion Telescopes and Binoculars introduced the StarBlast, a 4.5-inch Newtonian reflector designed mainly for kids. The StarBlast caught on with adults as well, from novices looking for a user friendly first scope to veterans wanting something portable. (See "Orion's StarBlast" in the January 2004 issue of *Astronomy*.) The "Little Scope That Could" proved to be such a success that Orion decided to give it a big brother. Enter the new StarBlast 6.

In creating this telescope, Orion didn't have to invest a lot in development. The company took the tube assembly from its Astroview 6, a 5.9-inch (150 millimeters) f/5 rich-field reflector, and placed it on a scaled-up version of the original StarBlast mount. Orion replaced the Astroview's 6x30 optical finder with a less costly red-dot reflex sight and added a navigation knob to the tube's front. Too bad Orion didn't go with the eye-pleasing teal color found on the original StarBlast tube. That would allow for a family to have a matching pair of parent and child StarBlasts.

This telescope is a Newtonian reflector. Its mirror measures 5.9 inches (150 millimeters) in diameter, and, from a dark site, will show you stars as faint as magnitude 13.6.

Setup and operation

Those who dread assembly projects that take hours and require a workshop full of tools will appreciate the StarBlast 6. Because the base comes already assembled, you need only attach a pair of mounting rings to it (with the supplied Allen wrench), clamp the tube in the rings, and add the finder and the eyepiece tray. You'll need a Phillips-head screwdriver for the latter. Complete assembly takes about a half hour.

Close inspection showed that the optical alignment was slightly off right out of the box. This wouldn't hinder general use, but it could compromise high-power images. Thanks to clearly written and illustrated instructions in the user manual and a supplied collimation cap, fine-tuning the alignment was easy. The StarBlast 6's short tube also let me adjust the primary mirror while peering through the collimation cap. In a matter of minutes, the scope was ready.

Because the eyepiece of the StarBlast 6 is never higher than 28 inches (71 centimeters) above the ground, using this scope brought me to my knees — literally. Orion recommends placing the instrument on a sturdy table or car hood. I opted for the table. While the mount is steady (vibrations ceased within seconds of my tapping the tube), it's at the mercy of the platform chosen to elevate it.

Like the original StarBlast, Orion's StarBlast 6 is user friendly. Lightweight (23.5 pounds [10.7 kilograms]) and furnished with hand grips cut into the base, it transports easily. Teflon bearings and

Specifications

Orion's StarBlast 6

Type: Newtonian reflector
Mount: Modified Dobsonian
Primary mirror: 5.9 inches (150mm)
Focal length: 750mm
Focal ratio: f/5
Focuser: 1¼" rack-and-pinion
Finder: EZ Finder II red-dot reflex sight
Eyepieces: 25mm (30x) and 10mm (75x) Sirius Plössl eyepieces
Total weight: 23.5 pounds (10.7 kg)
Included: 25mm (30x) and 10mm (75x) Sirius Plössl eyepieces, collimation cap, *Starry Night* special edition desktop planetarium
Price: $249.95

Glenn Chaple *is a contributing editor of* Astronomy *who writes the "Observing Basics" column each month.*

Orion's StarBlast 6 combines good optics with easy portability. The optical tube attaches to an alt-azimuth mount. The EZ Finder II sits next to the focuser.

All photos: *Astronomy:* William Zuback

an adjustable tension knob permit smooth side-to-side (azimuth) and up-and-down (altitude) motion.

Two eyepieces, 25mm and 10mm Orion Sirius Plössls, yield magnifications of 30x and 75x, respectively. I used the former, with its 1.7° field of view, primarily as a search eyepiece for sky objects I targeted with the red-dot finder.

The 10mm Plössl generated the magnification a novice might want. The Moon, Saturn, Jupiter, and bright double stars like Mizar and Albireo all presented themselves well through this eyepiece.

Would the StarBlast 6 satisfy the demands of the seasoned amateur astronomer? Its portability certainly wins points. The fully assembled scope fit nicely in the passenger seat of my car. For lengthy excursions, I'd suggest removing the optical tube assembly and securing it in a protective case.

Targeting the sky

The 75x provided by the 10mm Plössl was fine for general sightseeing, but I wanted to see detail only higher magnification could provide. The Hercules Cluster (M13) is a case in point. Through the 10mm Plössl, this globular cluster was resolved but appeared smaller than I would have liked.

Doubling the magnification with a 2x Barlow lens not only enlarged the image but also increased the contrast, transforming M13 into a teeming stellar mass. The Barlow boost also improved views of the Ring Nebula (M57), the Whirlpool Galaxy (M51), Bode's Galaxy (M81), and the Cigar Galaxy (M82).

A single observation of the "Double Double" (Epsilon [ε] Lyrae) quickly erased any doubts I had that a telescope with an f/5 focal ratio like the StarBlast 6 could hold its own at high magnifications. At 75x through the 10mm Plössl, these close pairs were elongated but not cleanly resolved. Once again, adding the 2x Barlow did the trick.

On a whim, I decided to "go the max" and insert a 5mm eyepiece in the Barlow. I don't recommend this practice — Barlows are better with low- to medium-power eyepieces. At 300x, the theoretical upper magnification limit for a 6-inch scope, both pairs of the Double Double were spectacularly split.

Taking a fun-to-use scope like the StarBlast 6 for a test drive quickly evolved into a cosmic joy ride. Still, I found that I could roll up my sleeves and put it to work making brightness estimates of variable stars. Its wide field (when used with the 25mm Plössl) allowed me to capture the variable star and a useful quantity of nearby comparison stars. Using this eyepiece on an evening of less than ideal transparency, I was able to see stars as faint as magnitude 12.5. Switching to the 10mm eyepiece increased contrast, bringing in stars as faint as magnitude 13.

Two eyepieces come with Orion's StarBlast 6 telescope. A 25mm Sirius Plössl provides a magnification of 30x. A 10mm Sirius Plössl yields 75x. The eyepiece rack mounts to the base and holds three 1¼" eyepieces.

A scope for you?

I confirmed my impressions of the StarBlast 6 at a star party held at the Amateur Telescope Makers of Boston clubhouse. About a dozen club members put the telescope through its paces. Their general consensus confirmed my own findings.

Relatively inexpensive and easy to operate, the StarBlast 6 would make a worthy telescope for the beginner. If you're an experienced amateur astronomer, you'll appreciate this scope as a backup or travel instrument as long as you augment the 25mm and 10mm eyepieces with a 2x Barlow lens or a high-power eyepiece.

For the past 5 years, kids have been having fun with the original StarBlast. With the StarBlast 6, we grown-ups can have our turn.

Contact information

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Background image: Daniel B. Phillips

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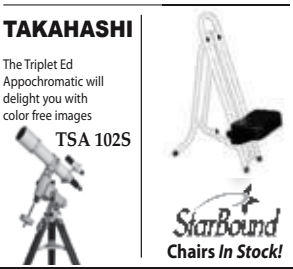

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January web extras

Web extras at www.Astronomy.com/toc bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

Astronomy's "Top 10 stories of 2008" p. 28
Get a jump on the major astronomy stories of 2009.

GLIMPSE images the Milky Way

"Is our galaxy running out of gas?" p. 38
Learn more on the GLIMPSE survey.

"Ask Astro" p. 62
Do galaxies have magnetic fields?

"Explore the sky's spooky reflection nebulae" p. 64
Download the van den Bergh catalog.

"The phases of Venus" p. 78
Glenn Chaple describes his astronomy resolutions for 2009.

"Follow the Charioteer" p. 80
Phil Harrington lists important celestial events through June 2009.

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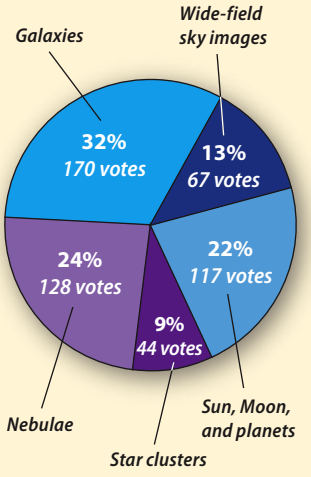

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You'll find the weekly question on the lower right side of the Astronomy.com home page.

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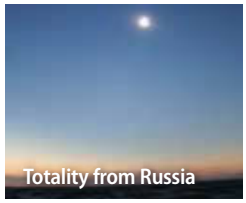
This month's top blogs

Editors put their spin on astronomy events in the staff blog. You can share your opinions, too. Read all of the editors' blogs at www.Astronomy.com/blog.

1 EXPLORING DUSTY DISKS AROUND BABY STARS
Trillions of miles away, disks and gas and dust encircle baby stars just a few million years old. **BY DANIEL PENDICK**

2 WHY I LOVE COSMOLOGY
Cosmology is weird stuff, completely crazy ideas, and very difficult to understand, but something about it just gets me. **BY LIZ KRUESI**

3 OUR IMAGE GALLERY FROM _ASTRONOMY_'S SOLAR ECLIPSE TRIP TO RUSSIA
From July 18 through August 2, 2008, *Astronomy* magazine had the pleasure of hosting a total eclipse expedition to Russia to see the August 1 total solar eclipse. **BY DAVID J. EICHER**


Totality from Russia

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Featured video

SEEING SUNSPOTS ON OTHER STARS
Associate Editor Daniel Pendick explains how astronomers study surface detail on a star beyond our solar system.

Tune us in

Each week, *Astronomy* magazine Senior Editor Michael Bakich, a master at explaining how to observe, posts a podcast about three objects or events you can see in the sky. Tune in to find out what targets to look for in this week's night sky. Past observable objects have included:

- **SQUARE OF PEGASUS**
- **GLOBULAR CLUSTER M15**
- **DUMBBELL NEBULA**
- **AND MANY MORE!**

GLIMPSE: NASA/JPL-Caltech/Ed Churchwell (Univ. of Wisconsin-Madison) and Sean Carey (Spitzer Science Center); Russian eclipse: David J. Eicher; M15: NASA and The Hubble Heritage Team (STScI/AURA)

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Observing Basics

by Glenn Chaple

The phases of Venus

Begin IYA2009 by replicating Galileo's observations of our "sister planet."

Happy International Year of Astronomy! Capitalizing on the fact that 2009 marks the 400th anniversary of Galileo's earliest telescopic forays into the night sky, the International Astronomical Union (IAU) is promoting a global celebration of astronomy.

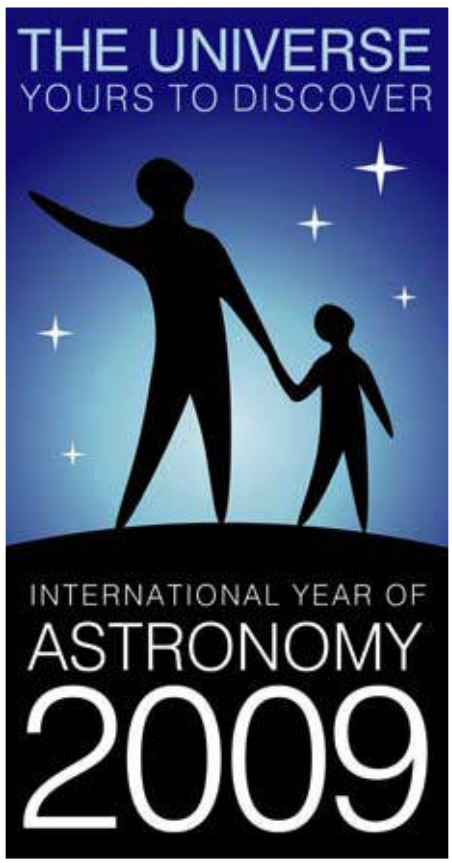
I like the comment *Astronomy* Senior Editor Michael Bakich made when I asked him about the magazine's plans for IYA2009. "At *Astronomy*," he replied enthusiastically, "every year is the Year of Astronomy!" I agree with that approach.

When I put together this column each month, I try to inject a little "wonder and discovery" into my writing. That being said, I was aware that the quadricentennial of Galileo's pioneering exploits would soon be upon us, and I might want to celebrate the occasion in some of my "Observing Basics" articles. IYA2009 fits my plans perfectly! This month and throughout the year, I'll focus on IYA2009 activities and the heavenly marvels Galileo explored 4 centuries ago.

And what better way to commence a celebration of Galileo's astronomical achievements than to repeat his observations of Venus. Through his telescope, Galileo found that Venus goes through a cycle of Moon-like phases, starting out as a small circular disk when it first appears in the evening sky, low in the west after sunset. In the months that follow, as Venus climbs higher above the horizon, its disk grows larger while transforming into a "half-Moon" shape — the phase Galileo observed when the planet arrived at greatest elongation from the Sun.

As Venus descends back into the Sun's glare, its disk looms larger yet and takes on the appearance of a thin crescent Moon. These phases reverse order when Venus reappears in the morning sky.

This was an astounding discovery. In Galileo's time, people commonly believed



The International Year of Astronomy marks the 400th anniversary of Galileo's use of a telescope to observe the skies. IYA2009

Earth was the center of the universe, with Venus situated between us and the Sun. Were this true, the planet would never appear more than half illuminated as seen from Earth.

Galileo's bold assertion that the venusian phases he had documented could happen only if Venus were circling the Sun, not Earth, shook the very foundation of 17th-century scientific, philosophical, and religious thought (and ultimately landed Galileo in trouble with the Roman Catholic Church, which at the time promoted an Earth-centered model of the universe).

It's fitting that as IYA2009 begins, Venus shines brightly in the evening sky — a beacon that attracts our attention as it did Galileo's centuries ago. In fact, on New Year's Eve 2008, Venus pairs up with a crescent Moon to form a striking after-sunset sight in our western sky — a heavenly way to sign off 2008. Greatest elongation occurs January 14, after which Venus drops rapidly toward the western horizon. By mid-March, you'll have a hard time ferreting Venus out of the glare of the setting Sun.

To document Venus' changing phases, make a weekly telescopic observation. You won't need high power — a magnification of 50x to 100x will suffice.

Don't expect to see much in the way of planetary detail. Venus may mimic our Moon's phases, but that's pretty much where the similarity ends. Our airless Moon presents us with spectacular cratered terrain, making it a favorite for backyard astronomers. Venus, by contrast, is veiled by a dense cloud-laden atmosphere. The sunlit portion of Venus you see will appear white and featureless.

IYA2009 provides a wonderful opportunity for us to connect with the night sky. If you're a novice skygazer, you can immerse yourself in backyard astronomy by following in Galileo's footsteps and repeating his historical observations (don't worry — I'll be here to help you). Veteran amateur astronomers who engage in public outreach programs will have a chance to relive those simple cosmic adventures that hooked them on astronomy. To get more information about IYA2009, log on to www.astronomy2009.org.

Next month: We retrace Galileo's telescopic study of Orion. Clear skies!

Read Glenn Chaple's New Year's resolutions at www.Astronomy.com/toc.

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Binocular Universe

by Phil Harrington

Follow the Charioteer

As the Milky Way passes through Auriga, Capella shines high in the winter sky.

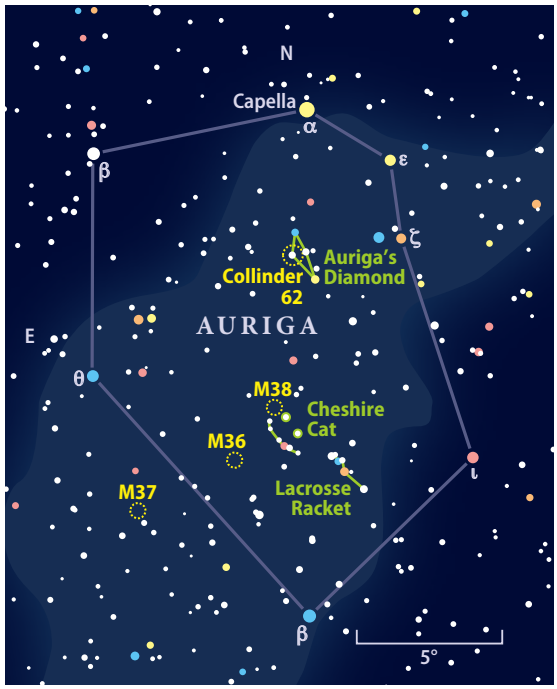
The bright star Capella (Alpha [α] Aurigae) lights the top of our evening sky this month as it glides silently overhead. Shining at magnitude 0.08, Capella is the sixth-brightest star in the night sky. No wonder it draws so much attention all winter long.

You may have read somewhere that Capella is a yellow star like our Sun. That's true. In fact, it's true twice over. Capella is actually a close-set binary system. The stars are separated by only about 70 million miles (110 million kilometers), the distance between our Sun and Venus. As such, they are not visible individually.

Studies, however, show that both are spectral type-G, like our Sun. That means all three stars have roughly the same surface temperatures. But while our Sun is a yellow dwarf star, both Capellas are yellow giants, each far larger and more luminous than our home star. To put things in perspective, were we to view our Sun from Capella's distance of 43 light-years, it would shine only at about 6th magnitude.

The winter Milky Way that passes through Capella's home constellation, Auriga the Charioteer, brings with it many binocular sights. Three that come to mind are the open clusters **M36**, **M37**, and **M38**. All are evenly spaced along a line that goes from northwest to southeast through Auriga's hexagonal body.

By centering your binoculars on the midway point between the stars El Nath (Beta [β] Tauri) and Theta (θ) Aurigae, you should notice two hazy smudges of light near the edge of the view. M37, in the southeastern corner of the field, looks like a large, softly glowing cloud. M36, near the northwestern edge, is noticeably smaller, but it may reveal several faint suns poking out from its soft glow.



Auriga the Charioteer is the home of many celestial highlights, including open clusters M36, M37, M38, and Collinder 62, and close-set binary star system Capella (Alpha [α] Aurigae). *Astronomy*: Roen Kelly

By shifting your aim so that M36 is in the southwest corner of the field of view, the third Messier cluster, M38, will move into the opposite side of the field. But I can't promise much because M38 is the least impressive of the three. It looks a little larger, but less distinct, than M36 and may also show a few faint points shining from within.

Do you get the feeling you're being watched? You are when you're viewing M38. Just to the cluster's south, there's a fun grouping of stars — an asterism — that looks like the smiling face of the **Cheshire Cat** from *Alice in Wonderland*. That's how Ben Cacace from New York first put it when he bumped into the pattern in 2002. He describes it as "made up of eight stars ranging from 5th to 7th magnitude, with two stars for the eyes and another six in an arc for the mouth." Depending on when you look toward Auriga, the Cat may be lying on its side or standing upside down.

There's another, even brighter asterism of a half dozen stars to the Cat's southwest that you can actually see with unaided eyes, given fairly dark skies. Some know it as the Leaping Minnow, but to me it looks more like the profile of a **Lacrosse Racket**. Four stars — 17, 18, 19, and IQ Aurigae — make up the racket's net, while 14 and 16 Aurigae are the handle. It must have been some game because the handle appears bent or even broken in the middle.

Scanning north back toward Capella, pause at the diamond-shaped asterism formed by the 5th-magnitude stars Lambda (λ) and Rho (ρ) Aurigae, and SAO 40248 and 40290. Like Capella and our Sun, Lambda is a type-G star, and may show a slightly yellowish tint through binoculars.

The other three diamond stars are all hotter, type-A white stars. Like the Lacrosse Racket, **Auriga's Diamond** can be seen without any optical aid on dark nights as a hazy smudge of light. Some star atlases note that SAO 40290 belongs to the weakly concentrated open star cluster **Collinder 62**. But you're hard-pressed to tell the cluster stars apart from those lying in front of or behind them.

If you have suggestions or observations, e-mail me at phil@philharrington.net. Until next time, remember that two eyes are better than one.

Preview celestial events for the first half of 2009 at www.Astronomy.com/toc.

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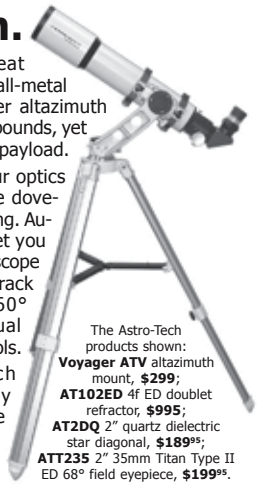
The Astro-Tech products shown: **Voyager ATV** altazimuth mount, **$299**; **AT102ED** 4f ED doublet refractor, **$995**; **AT2DQ** 2" quartz dielectric star diagonal, **$189.95**; **ATT235** 2" 35mm Titan Type II ED 68° field eyepiece, **$199.95**.

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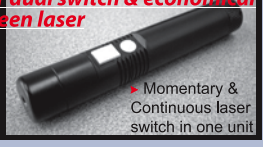
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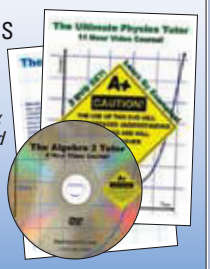

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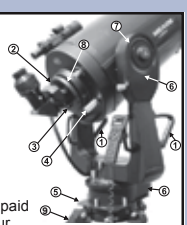

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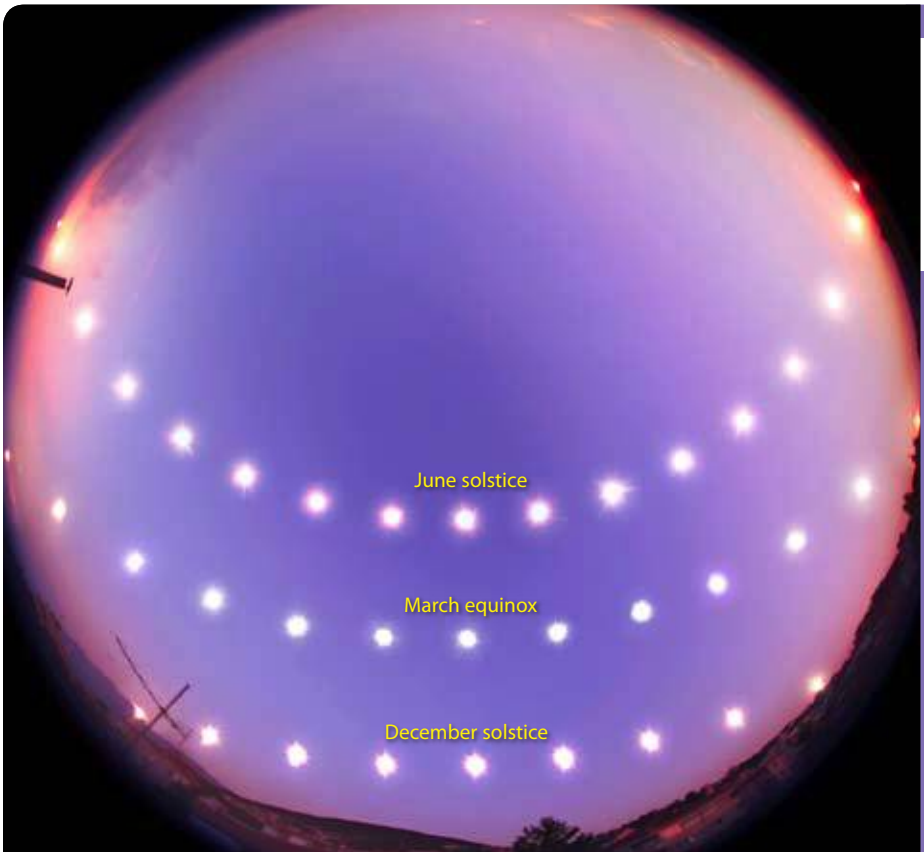

Equinoxes and solstices

The Sun's midday altitude changes through the year by 47° because Earth's axis tips 23.5°. When the northern part of the axis points at the Sun, it's the June solstice, and summer begins in the Northern Hemisphere. The Sun lies 23.5° above the celestial equator. Six months later, at the December solstice, the Sun lies 23.5° below the celestial equator. At the two midway points, the equinoxes occur. This composite by Tunç Tezel occupied 3 days over a 6-month span. His hometown of Bursa, Turkey, sits at a latitude of 40°11' north.

^ Solar extremes (Canon EOS 5D digital SLR, 8mm fisheye lens, taken December 21, 2007, March 20, 2008, and June 20, 2008) • Tunç Tezel, Bursa, Turkey

> Keenan's System (NGC 5216 [left] and NGC 5218) lie in Ursa Major about 17.3 million light-years away. American astronomer Phillip C. Keenan noted this double galaxy in 1935. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.4, ST10-XME CCD camera, LRGB image with exposures of 210, 70, 98, and 156 minutes, respectively) • Martin Winder, Linz, Austria; processed by Warren Keller, South Orange, New Jersey

^ **The zodiacal light** appears as a bright column of light passing through the winter Milky Way. Orion sits to the left of the zodiacal light, and Taurus and the Pleiades lie within it. (Hutech modified Canon XTi digital SLR, Sigma 8mm f/3.5 fisheye lens at f/4, 30-minute exposure) • Chris Schur, Happy Jack, Arizona

^ **A celestial lineup** occurred July 5, 2008, with fireworks as a bonus. From top left to bottom right, the objects are Saturn, Mars, Regulus, and the 2-day-old crescent Moon. (Nikon D80 digital SLR, Nikon 18-200mm lens set to 50mm at f/4.5, ISO 800, 8-second exposure, taken at Harrington Beach State Park, Lake Church, Wisconsin) • Ernie Mastroianni, Whitefish Bay, Wisconsin

> **The Pelican Nebula** (IC 5067–70) in Cygnus adjoins the North America Nebula (NGC 7000). Both are emission nebulae, best seen through OIII filters. (10-inch Takahashi BRC 250 Baker Ritchey-Chrétien telescope at f/5, FLI Proline 16803 CCD camera, Hα/SII/OIII image with 4 hours of exposure through each filter, plus 80-minute exposures through R, G, and B filters) • Larry Van Vleet, Denver, Colorado

reader gallery

<IC 4592 (lower left) and IC 4601 (upper right) in Scorpius are reflection nebulae. They shine because particles in the nebulosity reflect and scatter light from a nearby star. (10-inch ASA Astrograph at f/3.8, Apogee U16M CCD camera, LRGB image with exposures of 1.1, 1, 1, and 1.1 hours, respectively) • Gerald Rhemann, Vienna, Austria

^Comet C/2007 W1 (Boattini) was a binocular object in the morning sky during early July. It was on the Taurus-Eridanus border at the time of this image. (3.2-inch Orion ED80 refractor, Canon 350D digital SLR, ISO 800, 12 three-minute guided exposures, taken July 2, 2008, from Nambucca Heads, Australia) • Mike Salway, Wyoming, Australia

^Globular cluster M19 in Ophiuchus is the sky's most oblate globular. Foreground interstellar dust also partially obscures this object. (14-inch Celestron CGE-14 Schmidt-Cassegrain telescope, Starlight Xpress MX-916 CCD camera, LRGB image with exposures of 45, 20, 12, and 16 minutes, respectively) • Al Kelly, Friendswood, Texas

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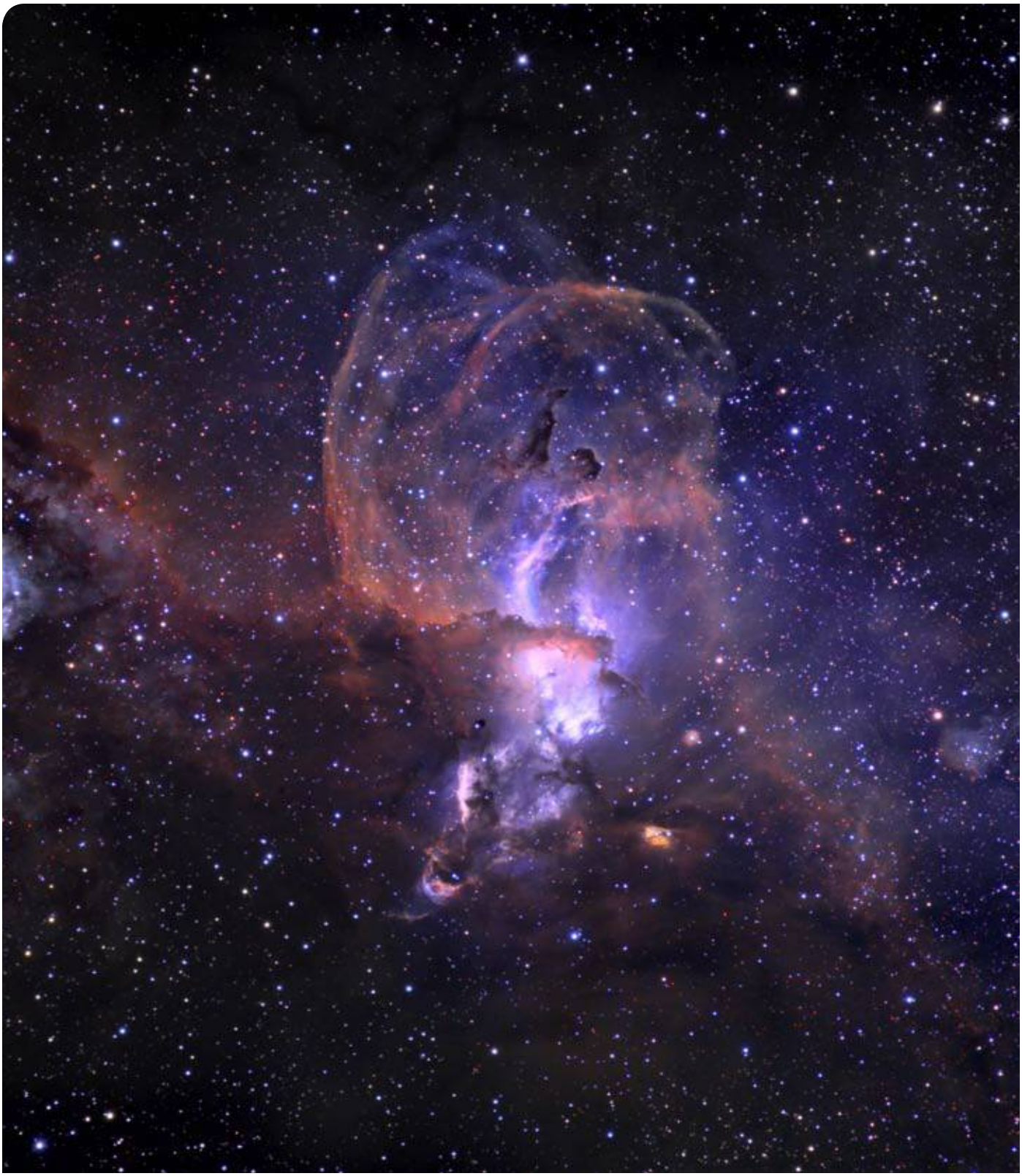

Emission nebula NGC 3576 in Carina is a region where hot stars are pushing gas clouds into huge bubbles. The electric-blue area hides a young star cluster, from which powerful stellar winds emanate. Dark nebulae north of the nebula's center are about 2 light-years in diameter and are called Bok globules. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee Alta 16803 CCD camera, Hα/SII/OIII image with exposures of 240, 180, and 150 minutes, respectively, plus 60-minute exposures through R, G, and B filters) • Ken Crawford, Camino, California

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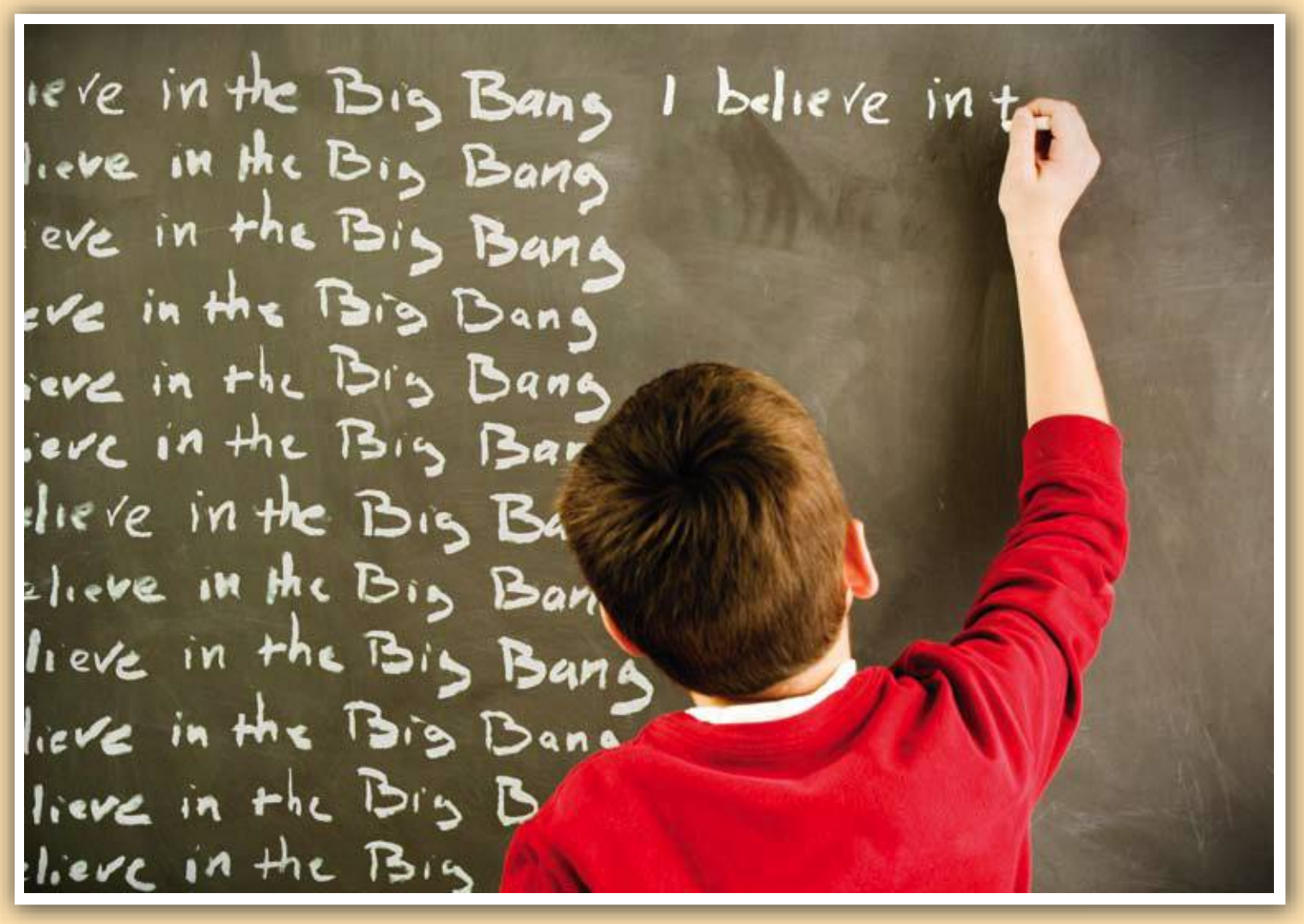

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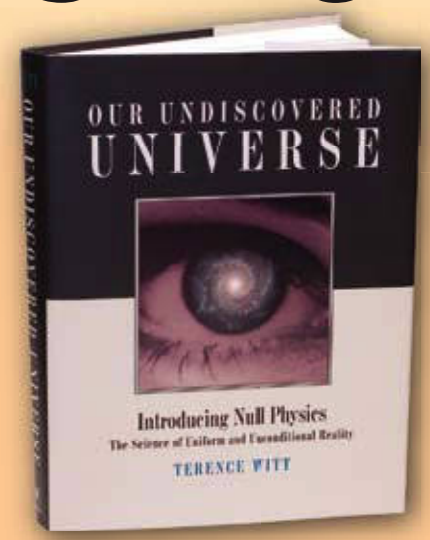

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New	First	Full	Last
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Jan. 26	Feb. 2	Feb. 9	Feb. 16
Feb. 24	March 4	March 10	March 18
March 26	April 2	April 9	April 17
April 24	May 1	May 9	May 17
May 24	May 30	June 7	June 15
June 22	June 29	July 7	July 15
July 21	July 28	Aug. 5	Aug. 13
Aug. 20	Aug. 27	Sept. 4	Sept. 11
Sept. 18	Sept. 26	Oct. 4	Oct. 11
Oct. 18	Oct. 25	Nov. 2	Nov. 9
Nov. 16	Nov. 24	Dec. 2	Dec. 8
Dec. 16	Dec. 24	Dec. 31	

All dates are for the Eastern time zone. A Full Moon rises at sunset and remains visible all night; a New Moon crosses the sky with the Sun and can't be seen.

THE MOON is Earth's nearest neighbor and the only celestial object humans have visited. Because of its changing position relative to the Sun and Earth, the Moon appears to go through phases, from a slender crescent to Full Moon and back. The best time to observe the Moon through a telescope comes a few days on either side of its two quarter-phases. For the best detail, look along the terminator — the line separating the sunlit and dark parts. NASA

MARS shines big and bright late this year. The Red Planet first becomes visible in the morning sky during February, although it doesn't grow prominent until summer. It hits its stride in December, as it prepares for opposition in January 2010. When viewed through a telescope, the planet's icy poles should stand out. Other features, such as dusky plateaus, are harder to see but show up as contrasting shades of orange and brown. Also watch as Mars passes through the Beehive star cluster this autumn. HST

JUPITER'S dynamic face shows an alternating series of dark belts and brighter zones pocked by the Great Red Spot. Even through a small telescope, the planet's four biggest moons — Io, Europa, Ganymede, and Callisto — appear conspicuous. You may see dramatic movement of these bright moons during the course of a single night. Jupiter reaches its peak in August, when it appears biggest and brightest, although it's a fine sight from February until early December. NASA/JPL/SSI

SATURN may be known as the ringed planet, but it doesn't look like one this year. Throughout 2009, the rings tilt nearly edge-on to our line of sight and appear at best as a thin line that bisects the planet's disk. Saturn shines brightest at opposition in March, when the rings tilt 3° to our line of sight. Earth passes through the ring plane in September. Spend some time this year observing the planet's disk and watching the big moon Titan and its shadow transit Saturn. HST

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WINTER

The sky

Winter boasts the brightest stars of any season. Orion the Hunter dominates the evening sky this time of year. Its seven brightest stars form a distinctive hourglass pattern. The bright blue star marking Orion's left foot is Rigel, and the ruddy gem at his right shoulder is Betelgeuse. The three stars of the Hunter's belt point down to Sirius, the brightest star in the night sky, and up to Aldebaran, the eye of Taurus the Bull. Above Orion lies the constellation Gemini the Twins.

Deep-sky highlights

The Pleiades (M45) is the brightest star cluster in the sky. It looks like a small dipper, but it is not the Little Dipper.
The Orion Nebula (M42), a region of active star formation, is one of the showpieces through telescopes of all sizes.
The Rosette Nebula (NGC 2237–9), located 10° east of Betelgeuse, presents an impressive cluster of stars and a gaseous nebula.
M35 in Gemini the Twins is a pretty open cluster, best viewed with a telescope.
Castor in Gemini is easy to split into two components with a small telescope, but the system actually consists of six stars.

SPRING

The sky

The Big Dipper, the most conspicuous part of the constellation Ursa Major the Great Bear, now rides high in the sky. Poke a hole in the bottom of the Dipper's bowl and the water would fall on the back of Leo the Lion. The two stars at the end of the bowl, called the Pointer Stars, lead you directly to Polaris, the North Star. From the bowl's top, simply go 5 times the distance between the Pointers. Spring is the best time of year to observe a multitude of galaxies. Many of these far-flung island universes, containing hundreds of billions of stars, congregate in northern Virgo and Coma Berenices.

Deep-sky highlights

The Beehive Cluster (M44) was used to forecast weather in antiquity. It is a naked-eye object under a clear, dark sky, but it disappears under less optimal conditions.
M5, a conspicuous globular cluster, lies between the figures of Virgo the Maiden and Serpens Caput the Serpent's Head.
The Whirlpool Galaxy (M51) is a vast spiral about 30 million light-years away.
M81 and **M82** in Ursa Major form a pair of galaxies that can be spotted through a low-power eyepiece.

Star maps by *Astronomy*: Roen Kelly

2009 EVENTS

Jan. 3 Quadrantid meteor shower peaks

Jan. 4 Mercury is at greatest eastern elongation

Jan. 14 Venus is at greatest eastern elongation

Jan. 26 Annular solar eclipse (Indonesia)

Feb. 25 Asteroid Ceres is at opposition

March 8 Saturn is at opposition

April 22 Lyrid meteor shower peaks

April 26 Mercury is at greatest eastern elongation

June 5 Venus is at greatest western elongation

June 23 Pluto is at opposition

July 21 Total solar eclipse (eastern Asia)

Aug. 14 Jupiter is at opposition

Aug. 17 Neptune is at opposition

Sept. 4 Earth passes through Saturn's ring plane

Sept. 17 Uranus is at opposition

Oct. 5 Mercury is at greatest western elongation

Oct. 21 Orionid meteor shower peaks

Nov. 17 Leonid meteor shower peaks

Dec. 14 Geminid meteor shower peaks

Dec. 31 Partial lunar eclipse

Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

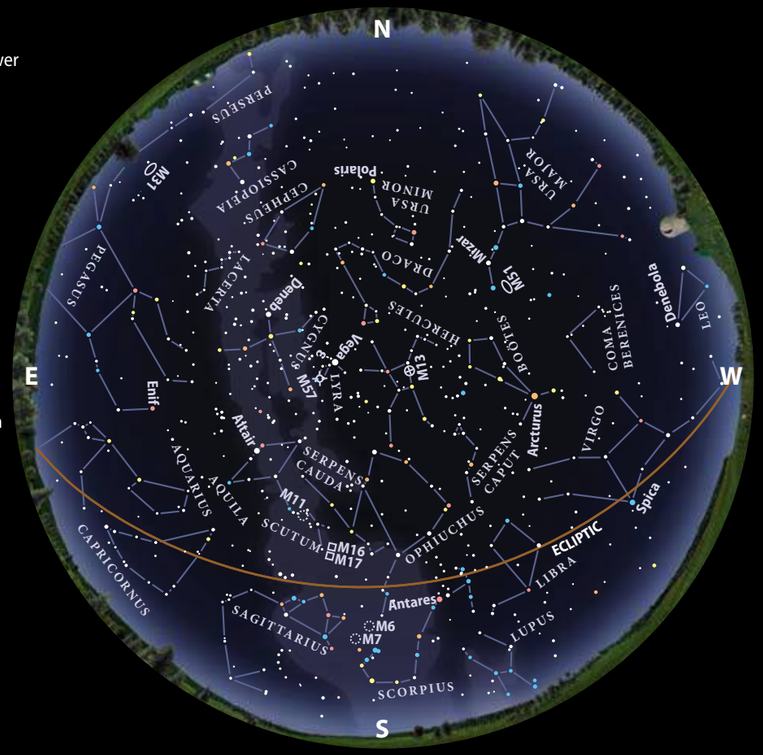
SUMMER

The sky

High in the sky, the three bright stars known as the Summer Triangle are easy to spot. These luminaries — Vega in Lyra, Deneb in Cygnus, and Altair in Aquila — lie near the starry path of the Milky Way. Following the Milky Way south from Cygnus, we find the center of our galaxy in the constellation Sagittarius the Archer. Here, you will find countless star clusters and glowing gas clouds. Just west of Sagittarius lies Scorpius the Scorpion, which contains the red supergiant star Antares as well as M6 and M7, two brilliant clusters that look marvelous at low power.

Deep-sky highlights

The Hercules Cluster (M13) contains nearly a million stars and is the finest globular cluster in the northern sky.
The Ring Nebula (M57) looks like a puff of smoke through a medium-sized telescope.
The Omega Nebula (M17) looks like the Greek letter of its name through a telescope at low power. This nebula also is called the Swan.
The Wild Duck Cluster (M11) is a glorious open star cluster. On a moonless night, a scope will show you more than 50 stars.



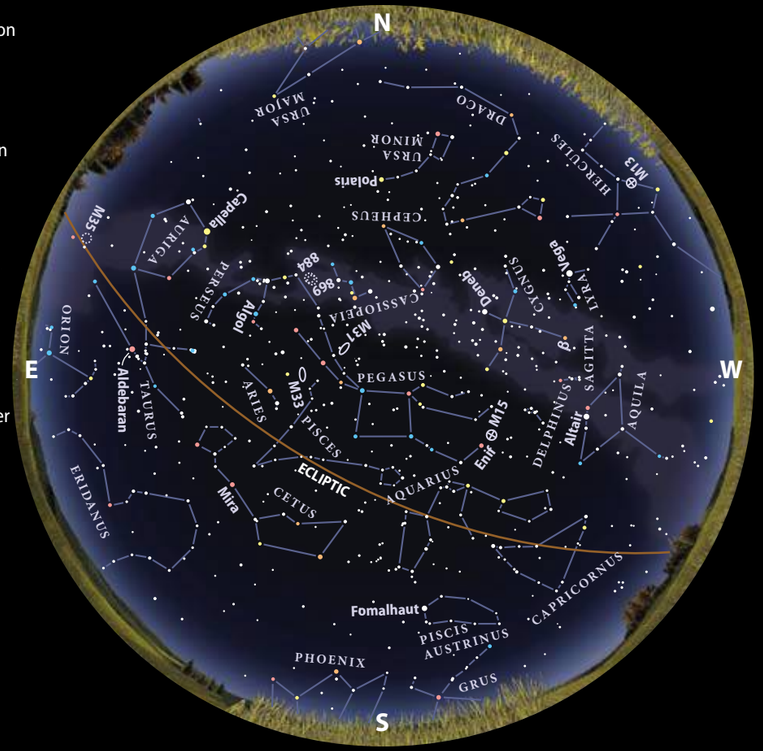
AUTUMN

The sky

The Big Dipper swings low this season, and from parts of the southern United States, it even sets. With the coming of cooler nights, Pegasus the Winged Horse rides high in the sky as the rich summer Milky Way descends in the west. Fomalhaut, a solitary bright star, lies low in the south. The magnificent Andromeda Galaxy (M31) reaches its peak nearly overhead on autumn evenings, as does the famous Double Cluster. Both of these objects appear as fuzzy patches to the naked eye under a dark sky.

Deep-sky highlights

The Andromeda Galaxy (M31) is the brightest naked-eye object outside our own galaxy visible in the northern sky.
The Double Cluster (NGC 869 and NGC 884) in Perseus consists of twin open star clusters. It's a great sight through binoculars.
M15 in Pegasus is a globular cluster containing hundreds of thousands of stars, many of which can be glimpsed with a medium-sized telescope.
Albireo (Beta [β] Cygni), the most beautiful double star in the sky, is made up of stars colored sapphire and gold.



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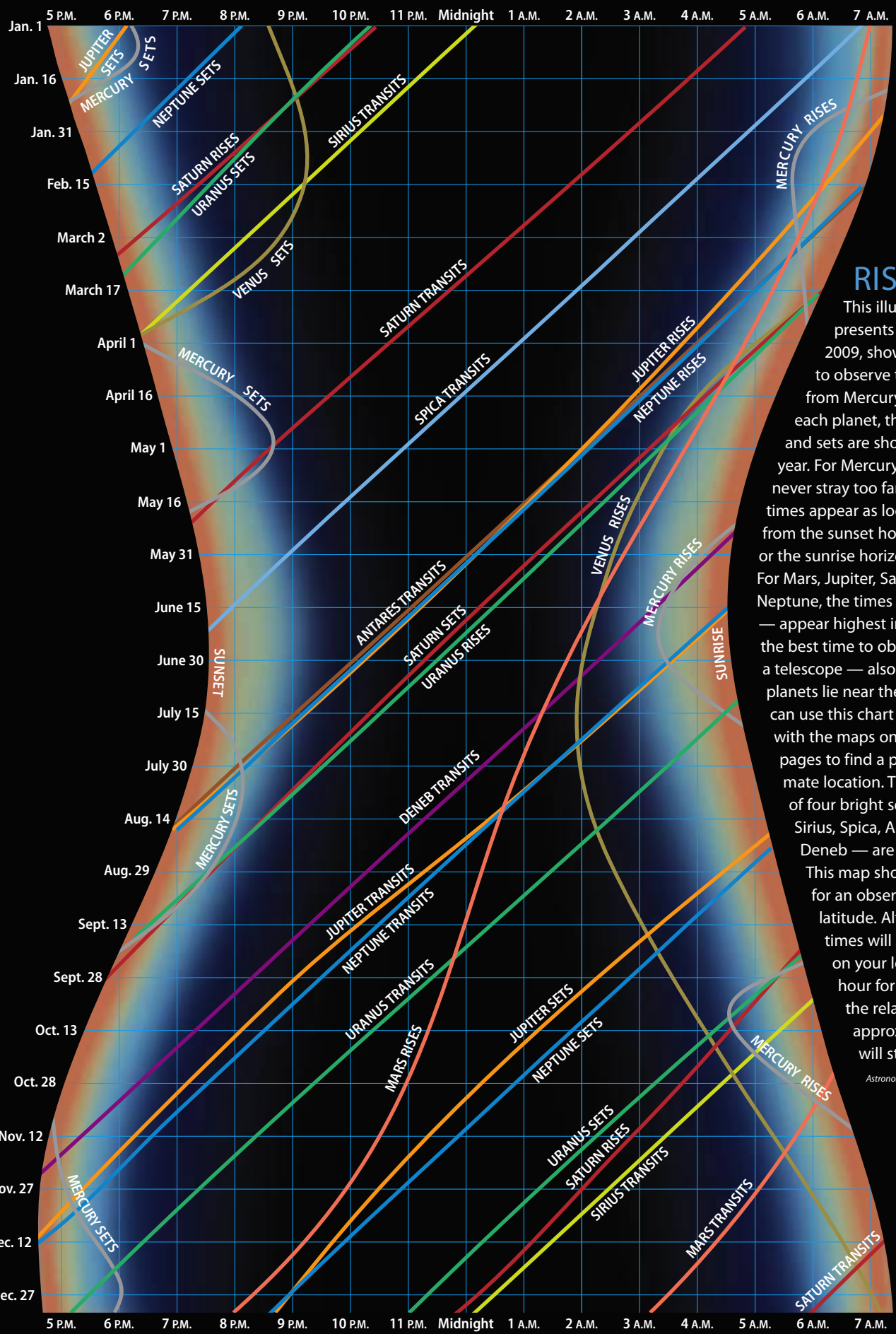

RISE & SET

This illustration graphically presents the night sky for 2009, showing the best times to observe the major planets, from Mercury to Neptune. For each planet, the times when it rises and sets are shown throughout the year. For Mercury and Venus, which never stray too far from the Sun, these times appear as loops coming up from the sunset horizon (on the left) or the sunrise horizon (on the right). For Mars, Jupiter, Saturn, Uranus, and Neptune, the times when they transit — appear highest in the sky and provide the best time to observe them through a telescope — also are shown. All the planets lie near the ecliptic, so you can use this chart in conjunction with the maps on the previous pages to find a planet's approximate location. The transit times of four bright seasonal stars — Sirius, Spica, Antares, and Deneb — are included as well. This map shows local times for an observer at 40° north latitude. Although exact times will vary depending on your location (add 1 hour for daylight time), the relative times and approximate positions will stay the same.

Astronomy: Rick Johnson